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NATURAL RESOURCE IMPACT ASSESSMENT
AND
NATURAL RESOURCE RESTORATION PLAN

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

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6-105

JULY 1997

U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

20300-RP-0002 REV. B
212E-PL-0003 REV. C

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Department of Energy

Ohio Field Office
Fernald Area Office
P. O. Box 538705
Cincinnati, Ohio 45253-8705
(513) 648-3155

AUG 27 1997

DOE-1265-97

Mr. Bill Kurey
U.S. Fish & Wildlife Service - Suite H
6950 American Parkway
Reynoldsburg, Ohio 43068

Dear Mr. Kurey:

REVISED FERNALD NATURAL RESOURCE IMPACT ASSESSMENT AND RESTORATION PLAN

Enclosed please find the latest versions of the Fernald Natural Resource Impact Assessment (NRIA) and Natural Resource Restoration Plan (NRRP) for your review and concurrence. Both of the plans have been revised based on the comments received to date, as indicated by the redline/strikeout. The NRIA identifies our best assessment of natural resource impacts that have occurred at the Fernald Site as the result of releases under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The NRRP proposes a series of restoration projects to compensate for natural resource impacts that have ocurred or are expected to occur during remediation at the Fernald Environmental Management Project.

We are proposing that the Fernald Natural Resource Trustees reach consensus on these plans so that more detailed planning and public involvement can occur. The Department of Energy understands that consensus with the plans at this time does not preclude the NRRP from evolving throughout the remediation/restoration processes at the site. We are proposing that once consensus has been reached on the plans, a public workshop be held by the Natural Resource Trustees to reintroduce Stakeholders to the trustee process at Fernald and discuss the content of the plans and address any Stakeholder comments.

Questions regarding these plans or this correspondence may be directed to our Trustee Representative, Pete Yerace, at (513) 648-3161.

Sincerely,

Glenn Griffiths

for Jack R. Craig
Director

FEMP:Yerace

Enclosures: As Stated

Recycled and Recyclable

cc w/o encl:

N. Hallein, EM-42/CLOV
S. Bogart, DOE-OH
R. J. Janke, DOE-FEMP
J. Reising, DOE-FEMP
J. Sattler, DOE-FEMP
A. Tanner, DOE-FEMP
P. Yerace, DOE-FEMP
D. Carr, FDF/52-5
T. Hagen, FDF/65-2
A. Hunt, FDF/52-5
E. Woods, FDF/65-2
AR Coordinator/78

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Department of Energy

Ohio Field Office
Fernald Area Office
P. O. Box 538705
Cincinnati, Ohio 45253-8705
(513) 648-3155

AUG 27 1997
DOE-1265-97

Mr. Tom Schneider, Project Manager
Ohio Environmental Protection Agency
401 East 5th Street
Dayton, Ohio 45402-2911

Dear Mr. Schneider:

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AR Coordinator/78

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Ohio Field Office
Fernald Area Office
P. O. Box 538705
Cincinnati, Ohio 45253-8705
(513) 648-3155

AUG 27 1997
DOE-1265-97

Mr. Jim Chapman
U.S. Environmental Protection Agency
Region V - SRT-4J
77 West Jackson Boulevard
Chicago, Illinois 60604-3590

Dear Mr. Chapman:

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AR Coordinator/78

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Department of Energy

Ohio Field Office
Fernald Area Office
P. O. Box 538705
Cincinnati, Ohio 45253-8705
(513) 648-3155

AUG 27 1997
DOE-1265-97

Mr. Tim Hull
Office of Federal Facilities Oversight
Ohio Environmental Protection Agency
401 East 5th Street
Dayton, Ohio 45402-2911

Dear Mr. Hull:

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Ohio Field Office
Fernald Area Office
P. O. Box 538705
Cincinnati, Ohio 45253-8705
(513) 648-3155

AUG 27 1997
DOE-1265-97

Mr. James A. Saric, Remedial Project Manager
U.S. Environmental Protection Agency
Region V - SRF-5J
77 West Jackson Boulevard
Chicago, Illinois 60604-3590

Dear Mr. Saric:

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Ohio Field Office
Fernald Area Office
P. O. Box 538705
Cincinnati, Ohio 45253-8705
(513) 648-3155

AUG 27 1997

DOE-1265-97

Mr. Don Henne
U.S. Department of the Interior
Office of Environmental Policy & Compliance
U.S. Custom House
200 Chestnut Street - 217
Philadelphia, PA 19106

Dear Mr. Henne:

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LIST OF ACRONYMS

BTV	Benchmark Toxicity Value
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
DOE	Department of Energy
EPA	U. S. Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FMPC	Feed Materials Production Center
FRL	final remediation level
FS	Feasibility Study
gpm	gallons per minute
IAWWT	interim advanced wastewater treatment
mi	miles
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NRDA	Natrual Resource Damage Assessment
NRIA	Natural Resource Impact Assessment
OEPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
PAH	polynuclear aromatic hydrocarbons
PEIC	Public Environmental Information Center
RI	Remedial Investigation
ROD	Record of Decision
SEP	Sitewide Excavation Plan
SSOD	Storm Sewer Outfall Ditch
TQ	toxicity quotient

1.0 INTRODUCTION

The objective of this report is to present an ~~assesment of~~ the natural resource impacts at the Fernald Environmental Management Project (FEMP) as defined by ~~for consideration and concurrence of~~ the Fernald ~~Environmental Management Project (FEMP)~~ Natural Resource Trustees. ~~It~~ This assessment is being prepared to meet the regulatory responsibilities of the ~~FEMP~~ Fernald Natural Resource Trustees pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the National Oil and Hazardous Substance Pollution Contingency Plan (NCP). This report presents an assessment of past impacts and anticipated future impacts resulting from past releases of hazardous substances and planned remediation activities, as well as potential post-remedial residual impacts.

This Natural Resource Impact Assessment (NRIA) is designed to identify injury to, loss of, or destruction of natural resources (here and after referred to as impact) that has occurred at the ~~site~~ FEMP as a result of releases of CERCLA hazardous substances from past production operations and waste management processes, along with future remedial activities. Existing information has been utilized to assess the impacts of historic releases of CERCLA hazardous substances at the FEMP and the associated restoration activities that have been or will be undertaken. This impact assessment will meet the substantive requirements of an injury determination under CERCLA Section 107 by outlining all impacts ~~injuries~~ for which the Department of Energy (DOE) is liable due to releases or threat of releases of hazardous substances.

The FEMP Natural Resource Trustees (NRTs) have chosen to focus on a restoration-based approach to resolve their concerns rather than the pursuit of a formal Natural Resource Damage Assessment (NRDA) that would calculate natural resource injury and corresponding damages (dollar amounts). If this approach proves to be sufficient, the Trustees will be able to save the time and expense of an NRDA. Upon concurrence with this NRIA, the trustees will collectively develop a natural resource restoration plan, which will outline appropriate restoration activities to satisfy DOE's liability as a responsible party under CERCLA Section 107. Figure 1-1 provides the relationship of each of the NRT documents and the process for implementing restoration at the FEMP.

The restoration plan (which will compensate for natural resource impacts) will be fully integrated with the CERCLA remedial design process for the excavation and remediation of soil at the site. This will allow restoration planning to be accelerated by implementing activities in sequence with soil excavation and grading. The restoration plan will also provide a habitat equivalency analysis to ensure that proposed restoration activities are commensurate with the severity of the impacts outlined in the impact assessment. Both the impact assessment and the restoration plan will be made available to the public independently once all Trustees have concurred with the documents.

The FEMP Natural Resource Trustees have also prepared a letter of consensus describing the intended approach for implementing Natural Resource Trustee activities at the FEMP. The letter was signed in September, 1996 and submitted to the U.S. Environmental Protection Agency (EPA). In addition, the letter was made available to all FEMP Stakeholders through notices in various publications and availability in the FEMP Public Environmental Information Center (PEIC). This letter serves as a first step in formalizing an agreement among the Natural Resource Trustees to resolve natural resource impact issues at the FEMP through the restoration process. The process for resolving the natural resource impacts will be outlined in this plan and the above-mentioned restoration plan. A more formal Memorandum of Agreement may be established later in the FEMP Trusteeship process to further document and formalize conditions for resolution of Trustee issues at the FEMP.

1.1 Assessment Format

The approach for outlining impacts at the FEMP is to present past, future and residual impacts "area by area". The designation of FEMP "areas" for the purpose of this impact assessment is presented in Figure 1-~~1~~2. The "areas" are based on those outlined in the Sitewide Ecological Risk Assessment and the Miami University Biological and Ecological Characterization Survey. In some cases, the areas presented in the Sitewide Ecological Risk Assessment have been consolidated due to the similarity in habitat types.

Past and future impacts are addressed separately in this assessment. A past impact is identified when a release of hazardous substances has resulted in the contamination of a certain portion of the site or has resulted in the physical disturbance of a portion of the site or both. It is anticipated that areas of past impact to soils will be remediated to Final Remediation Levels (FRLs) and physically impacted during remedial action. The areal extent of the groundwater contamination is presented in acres and volume. However, the quantification of the groundwater impact differs from other impacts since it does not constitute a habitat. ~~and restoration of the resource cannot be based on acres.~~

The designation of future impacts identifies areas that will be disturbed during remedial actions or areas that will be impacted by the future spread of contamination and does not necessarily include areas of past impact for the purposes of calculated acreage. In other words, if an area is identified as a past impact it is not counted again as a future impact, unless separate impacts to habitat occur.

Removal actions and other interim response actions will be discussed as either contributing to or possibly mitigating past impact. In some instances, actions have already been implemented at the FEMP to address contamination issues (e.g., Waste Pit Area Storm Water Runoff Control) and it may be appropriate for the Trustees to provide DOE credit for such projects ~~take these into consideration~~ when considering the severity of impacts and subsequent level of required restoration. Likewise, past response actions may have caused impact to a certain area and it may be appropriate to identify those as past impacts when considering severity.

As stated above, the FEMP Natural Resource Trustees have agreed to evaluate natural resource impacts to the extent possible using the existing information presented in Section 1-2. Since the original objectives of the existing reports and surveys were not to determine natural resource injury, certain assumptions must be made within this assessment. For instance, the purpose of the Sitewide Ecological Risk Assessment was not to determine whether ecological receptors had been impacted. The purpose of the risk assessment was only to determine ~~that~~ whether there ~~is~~ was a *potential* for impact. The results of the ecological risk assessment have been used to determine the ecological impact contributing to each NRIA study area at the site. These impacts have been factored into the overall assessments of impacts outlined in this document. The FEMP Natural Resource Trustees must evaluate the severity of the potential ecological risks when determining appropriate restoration.

An important aspect of natural resource impact determination is the calculation of time frames. It is difficult to define time frames for all impacts using existing information, since establishment of detailed time frames for individual releases was not the intent of those documents. It has been assumed that past impacts could have occurred from 1952, the inception of production at the FEMP, and could continue until the onset of remedial activities. Where more detailed information is available, it is presented within the area-by-area assessments.

As stated above, once the Trustees have agreed upon the impacts that have occurred at the FEMP, they will then determine the appropriate restoration activities to compensate for those impacts. The Natural

Resource Restoration Plan will be ~~prepared as an environmental~~ referenced ~~document to~~ in the Sitewide Excavation Plan (SEP). The SEP will establish final grades for remediated areas of the site from which restoration will originate. In addition, monitoring of remediation activities will be implemented to identify unexpected impacts that may occur during remediation. The commitment for monitoring and reporting natural resource impacts will be included in the Integrated Environmental Monitoring Plan (IEMP). The procedures for monitoring will be included in the Natural Resource Impact Monitoring Plan (Figure 1-1). ~~The Natural Resource Impact Assessment, Natural Resource Impact Monitoring Plan and the Natural Resource Restoration Plan will be made available to the public and key stakeholders independently upon completion.~~

1.2 Primary Sources of Information

1.2.1 RI/FS Process, Records of Decision, and Remedial Design

Remedial Investigations (RI) and Feasibility Studies (FS) have been prepared for Operable Units 1-5 to identify the extent of contamination and evaluate available remedial action alternatives to address environmental concerns. A Proposed Plan and Record of Decision (ROD) follows each FS and documents the selected alternative following consideration of U.S. EPA, Ohio EPA, and public comments. The substantive requirements of the National Environmental Policy Act (NEPA) were integrated into each FS and ROD to evaluate the anticipated environmental impacts associated with the implementation of cleanup actions for each of the five operable units. These anticipated environmental impacts were based on the implementation of the identified selected remedy in each ROD and are subject to change throughout the remedial design and remedial action process.

Figure 1-~~2~~3 illustrates the extent of off-site uranium in soil above background concentrations around the FEMP (DOE 1995c). These soil concentrations ~~extend over~~ are approximately ~~6800~~ 6942 acres and are recognized as an impact within the impact assessment. However, the above-background concentrations of uranium do not necessarily constitute an impact to natural resources requiring compensatory restoration, as defined in 43 Code of Federal Regulations (CFR) 11. ~~Although~~ Soil contamination above background concentrations does constitute an impact to soils, it does not cause unacceptable risk to human or ecological receptors, and does not require remediation. Therefore, contamination above background would not ~~necessarily~~ require natural resource restoration.

Final Remediation Levels (FRL) ~~as established for the "industrial or recreational user"~~ at the site (DOE 1995d) have been used to determine past impact with respect to the areal extent of soil contamination.

~~This~~ The predicted "footprint" of soil excavation is shown on Figure 1-~~3~~4, and is used as the primary basis for establishing past impacts to soil throughout this assessment. Soil above FRL concentrations will be~~come~~ the primary driver for ~~restoration.~~ remediation. This figure also identifies areas of past ecological impact which are discussed throughout Section 2.0 as "Past Impacts" for each study area.

A similar approach has been used for determining groundwater impacts. Figure 1-~~4~~5 illustrates the extent of uranium in the Great Miami Aquifer that is above background 3 μg/l. As with soil, this is recognized as an impact even though it ~~may~~ does not require remediation and does not require ~~compensatory~~ natural resource restoration. For the purpose of quantifying impacts, the extent of contamination is limited to 20 μg/l. This concentration is the proposed standard for uranium in drinking water and is the cleanup level that has been agreed to in the OU5 Record of Decision (DOE 1995d).

1.2.2 Sitewide Ecological Risk Assessment

The Sitewide Ecological Risk Assessment is an appendix to the Operable Unit 5 Remedial Investigation and was conducted to determine if radiological and non-radiological contaminants present in various media associated with actions at the FEMP represent a current or future risk to ecological receptors inhabiting this facility and nearby areas, including the Great Miami River. These receptors include all organisms, exclusive of humans and domestic animals, that may potentially be exposed to FEMP site contaminants.

To evaluate potential exposure of ecological receptors to FEMP site contaminants, the FEMP property was divided into study areas based on habitat type and home-range size of potential ecological receptors. This approach allowed media-specific contaminant concentrations within a given habitat to be quantified, which allowed those habitats that may have received greater amounts of contaminants to be evaluated separately from less contaminated study areas.

Analytical data used to prepare this assessment are from the site-wide RI/FS database, which has been validated pursuant to EPA guidance. Although data have been collected since 1988, the Sitewide Ecological Risk Assessment has preferentially examined data collected in 1993, when available. In those instances when such data were limited, data collected before 1993 were evaluated.

In general, two separate risks were evaluated within the Sitewide Ecological Risk Assessment: non-radiological risks and radiological risks. For radiological risks, potential risks to ecological receptors due to chronic exposure to low-levels of radiological contaminants were evaluated. To calculate the internal and external doses, media- and site-specific data were evaluated in a model, and the results compared to a target level dose published in 1992 by the International Atomic Energy Agency. The basis for the target level dose is presented in the publication, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards* (International Atomic Energy Agency 1992).

Results from this risk assessment indicated that on- and off-property soil concentrations of radionuclides did not result in a radiological dose in excess of the target level dose (36.5 rad/year) used to evaluate the potential risk posed to ecological receptors exposed to radionuclide contaminants. The International Atomic Energy Agency (1992) has concluded there is no convincing evidence from the scientific literature that chronic radiation dose rates below 36.5 rad/year will harm animal or plant populations. All calculated doses conducted in this ecological risk assessment are below the trigger level dose of 36.5 rad/year. The highest calculated dose for any receptor was 3.12 rad/year, which is an order of magnitude lower than the threshold value of 36.5 rad/year. Therefore, the ecological risk assessment concluded that based on the measured levels of radioactivity on the FEMP, there is no threat of radiation effects to populations of terrestrial plants or terrestrial or aquatic animals.

For non-radiological risks, media-specific contaminants were compared to media-specific benchmark values (benchmark toxicity values or BTVs), which are literature-derived concentrations considered protective of ecological receptors. Contaminants exceeding these values were regarded as final contaminants of concern (COCs) and the relative risk each of these might pose to FEMP ecological receptors was evaluated.

In general, BTVs are obtained from a variety of sources and are updated on a regular basis. An exceedance of these BTVs does not indicate definitive proof of impact, only an increased probability of impact. Although the toxicity quotients (TQs) identify the magnitude to which the constituent exceeded the BTV, they do not estimate the probability or risk level. Although the BTVs often include general considerations of bioavailability, site specific conditions can often increase or decrease exposure. These include percent of clay for metals in soil, total suspended solids in surface water, and total organic carbon for non-polar compounds in sediment. Some of these conditions were preliminarily considered in the Sitewide Ecological Risk Assessment. It should be emphasized that BTVs are not threshold levels that drive the extent of excavation. BTV comparisons are a conservative screen that indicate where the potential for ecological impact exists.

The Sitewide Ecological Risk Assessment indicated that a number of non-radiological contaminants are present in soil, surface water, and sediment in concentrations that potentially pose a current risk to ecological receptors. These findings are discussed in greater detail later in this document. The remedial design approach for addressing ecological risks is found in ~~the Sitewide Excavation Plan and is summarized below. Addendum A~~ Appendix B C to the ~~Natural Resource Restoration Plan~~ Sitewide Excavation Plan.

~~As a preliminary step, ecological COCs will be qualitatively evaluated to determine if they represent a realistic risk to ecological receptors at the FEMP. As stated above, the Sitewide Ecological Risk Assessment was essentially a screening document, using a conservative approach for estimating ecological risks. By more closely considering the site specific factors that influence the applicability for each COC, a case will be made for the elimination of a particular COC from further consideration. For instance, the determination of a COC within a SERA study area may have been based on surface soil concentrations that have since been remediated as part of a removal action. Therefore, the risk from that COC no longer exists within the particular study area. In addition to updating representative concentrations, other factors will be considered, including background values, bioavailability, ecological receptor values, localization of contamination and the extent of FRL driven excavation. Results of the qualitative screen will be presented to the FEMP Natural Resource Trustees, regulators and other stakeholders for their concurrence.~~

~~Ecological COCs that appear to be a concern after the qualitative screening process may be investigated further, if necessary. A quantitative evaluation would provide a more definitive site-specific determination of ecological impacts from a particular COC. In general, quantitative evaluations would include one or more of the following exercises; additional sampling, toxicity testing, animal tissue analyses, and reference site comparisons. The specific methodologies for investigating each COC would be highly dependent on the COC and the area of interest. Project specific plans (PSP) would be developed for each COC in question that would specify the exact procedures to be used within a particular area to address each COC. These decisions will be made through each Integrated Remedial Design Plan (IRDP) in conjunction with the FEMP NRTs, Regulator, and other stakeholders. Results~~

~~of these activities, if needed, will be used to develop a strategy to ensure that any remaining ecological COCs are addressed within IRDPs.~~

~~Ecological COCs that remain a concern after the qualitative screen and/or the quantitative evaluation must be addressed within the appropriate IRDP and subsequent iterations of the NRRP. In addition to soil excavation, other options are potentially available to eliminate impacts from ecological COCs. Engineering controls, such as covering a certain area with clean fill or applying additives to the soil that reduce the bioavailability of a particular COC may be employed. Another option is the alteration of final land use plans within the NRRP to inhibit sensitive receptor organism exposure to a particular COC. For instance, if post excavation impacts will remain in an area slated for wetland mitigation, the NRRP may be revised so that an introduced grassland or other non natural resource-specific land use is utilized within that area. These decisions will be made through each IRDP in conjunction with the FEMP NRTs, Regulators, and other stakeholders.~~

1.2.2 [illegible]

~~Surface water and sediment ecological COCs will be addressed primarily through processes outlined in the IEMP. As with FRLs, it is anticipated that remediation of source materials (i.e. soil) will eliminate impacts to surface water and sediment.~~

1.2.3 Biological and Ecological Characterization of the Feed Materials Production Center

Researchers from Miami University conducted comprehensive surveys of the flora and fauna of the FEMP site in 1986 and 1987. Various methods were used to conduct on-property species counts of herbaceous and woody plants, terrestrial invertebrates, benthic macroinvertebrates, fish, birds, small mammals, and game animals. In addition, an attempt was made to evaluate the genetic structure of FEMP flora and fauna. Samples were collected to conduct electrophoretic analysis of select species of plants, insects, amphibians, benthic macroinvertebrates, and fish.

The goal of this research effort was to identify habitats and biota present at the FEMP site, determine the species abundance and distribution of FEMP site flora and fauna, and identify, if possible, "stress-induced" differences between on-property and off-property biota.

Findings from this effort prompted several follow-up studies on FEMP robins and spring peeper frogs and tadpoles. These follow-up studies are discussed further in Sections 2.4 and 2.6.

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1.3 FEMP Natural Resources

The FEMP, formerly known as the Feed Materials Production Center (FMPC), is a 1050-acre, DOE-owned, contractor-operated facility located in southwestern Ohio, about 18 miles (mi) northwest of downtown Cincinnati, Ohio. The facility is located just north of Fernald, Ohio, and lies on the boundary of Hamilton and Butler counties. Approximately 850 acres of the FEMP property are in Crosby Township of Hamilton County, and 200 acres are in Ross and Morgan Townships of Butler County. Southwestern Ohio lies within the Till Plains region of the Central Lowland Physiographic Province. This area is characterized by gently to steeply rolling hills, which were formed as a result of several periods of glaciation. The topography of the area ranges from approximately 500 feet above mean sea level (MSL) along the Ohio River to almost 900 feet MSL on the hilltops (DOE 1993).

In the vicinity of the FEMP site, the hilly topography is separated by broad, flat areas that comprise the floodplains of the larger surface water features. Prominent geographical areas in the vicinity of the FEMP site include the floodplains of the Great Miami River and the floodplains of the Whitewater River and Dry Fork Creek southwest of the FEMP (DOE 1993).

The principal groundwater resource within the region of the FEMP site is the Great Miami Aquifer, which has been designated as a sole-source aquifer under the provisions of the Safe Drinking Water Act and Ohio Administrative Codes. Principal sources of recharge for the Great Miami Aquifer include direct precipitation and natural and induced stream infiltration. Bedrock serves as a limited source of recharge in the area of the FEMP with water movement restricted through fractures and along bedding planes due to the impermeable nature of the shale units (DOE 1993).

In the vicinity of the FEMP, three surface water features predominate. These include the Great Miami River, Paddys Run, and a tributary to Paddys Run referred to as the Storm Sewer Outfall Ditch (SSOD). Paddys Run parallels the western property boundary of the site and flows south into the Great Miami River. The SSOD and headwater of the tributary are located in the southern portion of the FEMP site and feed into Paddys Run. The Great Miami River flows just east of the FEMP and exhibits meandering patterns that result in sharp directional changes.

The FEMP and surrounding areas lie in a transition zone between two distinct sections of the Eastern Deciduous Forest Province as described by Bailey (1978): the Oak-Hickory and the Beech-Maple forests. The region is characterized by the presence of a mosaic of these forest types. The Oak-

Hickory and Beech-Maple forest sections share many characteristics (e.g., white oak as a common species).

Terrestrial ecological communities on the FEMP site consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and the "reclaimed flyash pile area." The reclaimed flyash pile area coincides with the South Field and the Inactive Flyash Pile and was considered a distinct habitat by researchers at Miami University because of its status as an old field (Facemire *et al.* 1990). A total of 47 species of trees and shrubs, 190 species of herbaceous plants, 20 mammal species, 98 bird species, 10 species of amphibians and reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates were catalogued at the FEMP site by Miami University researchers.

Several surveys for threatened and endangered species have been conducted at the FEMP. Between 1993 and 1995, surveys were conducted for the federally-endangered Indiana bat (*Myotis sodalis*) and running buffalo clover (*Trifolium stoloniferum*), the state-endangered cave salamander (*Eurycea lucifuga*), spring coralroot (*Corallhorhiza wisteriana*), slender fingergrass (*Digitaria filiformis*), and mountain bindweed (*Polygonum cilinode*), and the state-threatened Sloan's crayfish (*Orconectes sloanii*). Results of these surveys show that the FEMP has a population of Sloan's crayfish within Paddys Run, and suitable habitat for the Indiana bat, running buffalo clover, and spring coralroot. All other threatened and endangered species surveys indicated no species or suitable habitat. Several state threatened or endangered migratory birds were sited on the FEMP during the Miami University study but are not actually residing on property. These include the northern harrier (*Circus cyaneus*), northern waterthrush (*Seiurus noveboracensis*), and dark-eyed junco (*Junco hyemalis*).

A site-wide wetlands delineation was conducted in January 1993 in accordance with the 1987 Army Corps of Engineers Wetlands Delineation Manual and was approved on August 12, 1993 by the U.S. Army Corp of Engineers, Louisville District. The purpose of the delineation was to determine the extent of jurisdictional wetlands and waters of the United States at the FEMP site so response actions could be planned to avoid or minimize impacts to these resources. Results from the site-wide delineation indicate a total of ~~35.9~~ 36.4 acres of jurisdictional freshwater wetlands on the FEMP site. Approximately 26 acres of these wetlands occur as forested wetlands in the northern woodlot.

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A watershed study on the forested wetland was completed in 1996. The results of the study will provide information as to the feasibility of expanding the forested wetland to support on-property wetland mitigation. If expanding the forested wetland is feasible, plans to do so will be factored into the Natural Resource Restoration Plan.

2.0 IMPACT ASSESSMENT

This section describes the extent of past impacts and anticipated future and residual impacts based on the format and information discussed above.

2.1 Groundwater

A summary of impacts to FEMP groundwater ~~and the Great Miami River~~ is presented below ~~and on Figure 2-1~~. This Impact Assessment will consider the Great Miami Aquifer with respect to past and anticipated future impacts. Remediation of perched groundwater will be addressed during soil excavation (discussed further below).

2.1.1 Great Miami Aquifer

2.1.1.1 Past Impacts

An assessment of past impact to the Great Miami Aquifer can be made from the conclusions of the OU5 RI. Using data collected in 1993, the OU5 RI demonstrated that uranium was the primary groundwater contaminant within the Great Miami Aquifer. As described in Section 1.2.1 and shown on Figure 1-45, past impacts to the Great Miami Aquifer are recognized as the extent of above-background uranium concentrations. For the purpose of quantifying impacts, the remedial action level of 20 μg/l was assessed. Using the current 20 μg/l total uranium contour as shown on Figure 2-1, the areal extent of contamination to be remediated within the Great Miami Aquifer is 172 acres. The total uranium remediation goal for the Great Miami Aquifer was obtained by using the proposed maximum contaminant level of 20 μg/l for uranium under the Safe Drinking Water Act (56 Federal Register 33050).

This contamination is primarily the result of six distinct point or line source plumes that originate from the following areas: the Waste Storage Area (1952); the stretch of Paddys Run adjacent to the Waste Storage Area (1952); Plant Six (1952); the Inactive Flyash Pile (1957), South Field (1957), and Active Flyash Pile (mid 1960s); the southern stretch of Paddys Run and the Storm Sewer Outfall Ditch (1951), and the stretch of Paddys Run south of New Haven Road (1951). It is reasonable to assume that the Great Miami Aquifer has been receiving contamination from these sources as long as they have been in place. Therefore, the time frames have been provided in parenthesis to indicate when the source was constructed or approximately when the source began contributing to the contamination of the aquifer.

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Researchers did not consider groundwater as a specific medium of concern in conducting the Sitewide Ecological Risk Assessment. It was assumed instead that surface water samples would reflect contaminant concentrations to which ecological receptors were exposed, regardless of the source of the contamination, be it groundwater, nonpoint, or point source discharge. Miami University researchers did not investigate groundwater in the site characterization study.

Other Actions

Several CERCLA Removal Actions have been conducted in recent years that have reduced contaminant loading to the Aquifer and migration of the off-property portion of the plume in the Great Miami Aquifer. The most influential of these is the South Groundwater Contamination Plume Removal Action. This removal action is designed to protect public health by pumping and treating uranium-contaminated groundwater in an area south of the FEMP site. The action consists of five parts. Part 1, initiated in May 1992, provides an alternate water supply to an industrial user affected by the contamination plume. Part 2, initiated in July 1992, consists of the installation of a recovery well system to remove the contaminated water and pump a portion of it to the FEMP site for treatment, monitoring, and discharge. It also includes increasing the pump-out capacity of the storm water retention basin to reduce the potential for future overflows. Pumping of the recovery wells is projected to continue for about 25 years. Part 3 is construction of an interim advanced waste water treatment (IAWWT) system to remove uranium from FEMP site waste water streams. Part 4, implemented through the FEMP's existing groundwater monitoring program, involves monitoring and institutional controls to prevent the use of contaminated groundwater by including more frequent monitoring of private wells located near areas of known contamination. Part 5 is additional investigations to identify the location and extent of any remaining contamination attributable to the FEMP site south (downgradient) of the recovery wells being installed under Part 3.

Implementation of the South Plume Removal Action has had a positive impact on natural resources by ~~increasing the ability to limit~~ preventing further migration of the plume. Well installation did result in the commitment of several acres of land for access roads and well heads.

Other Removal Actions have been beneficial to the Great Miami Aquifer by indirect reduction or elimination of contaminant sources. Examples of these are the Waste Pit Area Runoff Control and the Inactive Flyash Pile Removal Actions. Refer to Section 2.2 for a more detailed description of these Removal Actions.

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DOE also provided $5.4 million to partially fund the installation of a public water line to local residents. Residents/businesses in the vicinity of the FEMP and the contaminated groundwater plume were connected to the water line in the spring of 1996. This project essentially eliminated the need to use the Great Miami Aquifer as a drinking water source within the zone impacted by Fernald.

In addition to impacts to the Great Miami Aquifer, impacts to perched groundwater have also occurred as a result of past releases. Perched groundwater impacts have occurred in approximately 96 acres within the footprint of study Areas C, E, ~~G~~F, and G (Figure 2-2). Remediation of approximately 72 acres of perched groundwater contaminated above the FRL will occur as part of soil remediation. Since perched groundwater impacts have occurred in areas already identified as impacted in Figure 1-~~3~~4, the 96 acres will not be counted twice in calculating required restoration acreage. However, perched groundwater impacts should be considered when the severity of impacts in a specific study area are considered.

2.1.1.2 Future Impacts

According to the OU5 FS, anticipated future impacts include areas of the Great Miami Aquifer exceeding final remediation levels that will be restored through extraction, reinjection and treatment. Modeling to derive the base case groundwater remedy in the OU5 FS identified the need for 28 extraction wells with a combined maximum pumping rate of 4000 gallons per minute (gpm) from the extraction well system for 27 years. The 4000 gpm includes treated groundwater (1800 gpm) and untreated groundwater (2200 gpm) which equate to 9.4×10^8 and 1.1×10^9 gallons per year, respectively. Assuming the 4000 gpm is maintained for 27 years, a total of 5.0×10^{10} gallons of water from the Great Miami Aquifer will be pumped over approximately 27 years, until the proposed 20 μg/l drinking water standard is met. The accelerated cleanup plan calls for remediation or the Great Miami Aquifer in approximately 10 years. This effort requires the installation of eight additional extraction wells and an increase in the pumping rate to 4,700 gpm. The Baseline Remedial Strategy for Aquifer Restoration, which is currently under development, outlines the approach and schedule for aquifer restoration at the FEMP. The continued pumping of the wells will not impact the aquifer as a whole due to its size and volume and reinjection efforts. In addition, the aquifer does not function as a geological or ecological support mechanism and the risk of subsidence due to continued pumping is negligible.

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Groundwater extraction from the South Plume recovery well installed as part of Removal Action Number 3 (approved by EPA and implemented in 1993) has drawn groundwater contaminated above the uranium FRL further south (Figure 2-3). In order to remediate the Aquifer, continued pumping will result in groundwater contaminated above the FRL being drawn even further south towards the existing South Plume extraction wells in off-property areas. In effect, this will result in the migration of groundwater contaminated above the FRL into areas that are not currently contaminated above 20 μg/l. This will occur directly south of the FEMP property and is not expected to affect more than 15 additional acres (DOE 1997).

2.1.1.3 Residual Impact

After completion of the proposed remedy, there will be a certain amount of groundwater remaining that is below the 20 μg/l cleanup level yet still above the background concentration of 3 μg/l, which is difficult to quantify. Figure 2-3 shows approximately 11~~83~~98 acres of above-background contamination as of the completion of the Operable Unit 5 RI/FS. Since the extent of residual contamination remaining after remediation is unknown, it is assumed that the extent of this above background contamination will be similar to current conditions (i.e., about 11~~83~~98 acres). However, there are two factors influencing this estimate. First, the remedial action will pump and treat some quantity of groundwater below 20 μg/l. Second, once remedial actions have been completed, the remaining groundwater above background concentrations (but below the FRL) will dissipate over time, gradually decreasing in concentration until it reaches background conditions.

2.1.2 Great Miami River

2.1.2.1 Past Impacts

Samples of surface water from the Great Miami River were taken in 1993. Results of this sample effort reveal that there was some increase in uranium contamination downstream of the FEMP, as maximum concentrations (2.1 μg/l) were less than two times above background values (1.4 μg/l).. It is assumed that increased concentrations of uranium were present downstream of the FEMP from the inception of production (1952). In recent years, these concentrations have decreased as a result of improved stormwater control efforts and improved water treatment facilities. These improvements are reflected in results of surface water sampling conducted by the Radiological Environmental Monitoring department for inclusion in the annual Site Environmental Reports. A further discussion of various water quality improvements is provided in Section 2.2.

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Sediment samples collected in 1993 from the Great Miami River revealed total uranium concentrations similar to background values (3 mg/kg). Elevated levels of aluminum, beryllium, and zinc, as well as several volatiles and semi-volatiles, were detected in sediment samples. As is typical with a river of its size, sediments in the Great Miami River are influenced by a variety of point and non-point discharges.

A removal action under CERCLA was completed to remove contaminated soil ~~sediments~~ from the bank of the Great Miami River as part of the installation of the new outfall line from the site to the Great Miami River. Past site operations resulted in the contamination of the banks of the Great Miami River to above background levels due to the continuous discharge of uranium through the outfall line combined with past flood events. An additional remedial action was completed at Manhole 180 between the site and the Great Miami River to remove soil contaminated due to overflow during a flood event. Figure 2-4 shows contaminated areas of the Great Miami River.

Surface Water

The Sitewide Ecological Risk Assessment identified COCs to aquatic organisms within the Great Miami River (Table 2-1). For surface water upstream of the FEMP outfall, mercury and ammonia were identified as COCs. Downstream of the FEMP outfall, aluminum, cyanide, and cadmium were determined to be COCs. Seven COCs identified at the confluence with Paddys Run were cadmium, cyanide, lead, manganese, barium, aluminum, and bis(2-ethylhexyl)phthalate. Since chronic toxicity data was not available, manganese (found in the Great Miami River) and Di-n-octyl phthalate (found in Paddys Run) BTVs were based on lethal concentrations to 50 percent of test populations (LC_{50}) divided by 100. This method has been employed by the U.S. EPA Office of Pesticide Programs to protect sensitive wildlife species (Urban and Cook, 1986). The BTVs for the remaining constituents were based on either the Ambient Water Quality Criteria (AWQC) (EPA 1988a), Water Quality Advisory (EPA 1988b), or warmwater criteria (OEPA 1993). These values are considered to represent levels which are protective of aquatic organisms.

As indicated in the ecological risk assessment, the toxicity of many of the metals identified have been demonstrated to change depending on hardness (i.e., calcium and magnesium content of the water). The values were adjusted for hardness by using the average hardness of Paddys Run and the Great Miami River, not based on specific sample conditions. Several of the metals are also considered to be naturally occurring.

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Ecological risk to aquatic organisms in the Great Miami River is difficult to assess since there are many contributory (industrial, municipal, etc.) influences upstream of the FEMP effluent line. Fish studies conducted on the Great Miami River indicate that the FEMP has had no impact on the general fish population. In addition, no records of fish kills or fishing advisories were identified in the GMR near the FEMP.

Sediment

For sediments downstream of the FEMP outfall, barium, iron, lead, manganese, zinc, and phenanthrene were determined COCs. Sediments sampled at the confluence of Paddys Run showed barium, manganese, and zinc as COCs. The sediment BTVs identified in the OU5 Ecological Risk Assessment came from three literature sources which used different approaches in developing the protective levels:

- Long and Morgan (1991) used values called Effects Range - Lower (ER-L). The values were determined based on a distribution of sediment levels observed to cause deleterious effects to aquatic organisms. Many of these values were based on marine and estuary data but commonly used for freshwater systems. Based on the distribution of values an ER-L and ER-M (Median) were identified. The ER-L is generally considered to be protective of aquatic life as long as the sediment is not disturbed. The ER-M is considered to be harmful to an aquatic system.

- EPA developed "Sediment Quality Criteria for the Protection of Benthic Organisms" (1993). BTVs are developed from a model that assumes toxicity from sediment contamination is a function of the pore or interstitial water concentrations of the sediment contaminants. The Equilibrium Partitioning Model estimates the sediment levels required to have interstitial water concentrations greater than the AWQC by considering the total organic carbon of the sediment and physical properties of the constituents.

- Baudo, et al. (1990, "Sediments: Chemistry and Toxicity of In-Place Pollutants") based BTVs on summaries of various toxicity testing and field observations.

Drinking Water

The Sitewide Ecological Risk Assessment also considered the risk to terrestrial organisms that use the Great Miami River as a source for drinking water. This investigation revealed that upstream of the

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FEMP effluent, mercury was determined to be a COC. Downstream of the FEMP effluent, the COCs were aluminum, beryllium, and cadmium. At the confluence with Paddys Run, the COCs identified were aluminum, cadmium, and bis(2-ethylhexyl)phthalate. The drinking water BTV for aluminum was based on the AWQC and mercury was based on warmwater criteria from the OEPA (1993). Both the AWQC and warmwater criteria are considered protective of aquatic organisms. However, these values were used in the absence of drinking water criteria for wildlife or humans to preliminarily identify constituents which may pose a risk to ecological receptors which use the surface water body as a sole source of drinking water. Beryllium and cadmium BTVs were derived from the U.S. EPA's "Drinking Water Regulations and Health Advisories" (1994). The remaining BTVs is based on Ohio Environmental Protection Agency's (OEPA) "Ohio Water Quality Standards" (1993) established for drinking water.

Although several constituents were identified as a potential risk to terrestrial receptors drinking the surface water and toxicity quotients were calculated, the ecological risk assessment did not clearly indicate the magnitude of the risk. A toxicity quotient equal to or greater than 1 was considered an indication that the constituent may pose risk to one or more species. The greater the toxicity quotient value, the more the species may be affected. The interpretation of the magnitude of risk and potential impact associated with ecological receptors drinking surface water should consider the TQs.

The representative concentration compared to the drinking water standard was always the maximum detected value. This is extremely conservative when evaluating terrestrial receptors using the surface water as a drinking source. This assumes that all water consumption is from that location at that elevated level. A more realistic concentration would be the upper bound of the mean.

Although background conditions were taken into account, aluminum was identified as a potential drinking water risk above the drainage area of the production area, suggesting that the levels are in part a function of the natural presence of aluminum in soils and sediments. However, aluminum levels in the pilot plant drainage ditch and confluence of Paddys Run and the Great Miami River were noticeably elevated relative to the other areas and may be a function of sediment load. Similarly, cadmium was detected upstream of the production area at levels above those found at other on-property and off-property locations, suggesting that the source is not solely the FEMP. Mercury was identified at two locations as a potential risk to drinking water receptors; however, both locations are located upstream of the FEMP's primary influence.

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In general, the constituents identified should be considered as potential risk to ecological receptors but emphasis relative to FEMP impact should be placed on lead, beryllium, uranium, 1,2-dichloroethene, bis(2-ethylhexyl)phthalate, and Di-n-octyl phthalate.

Fauna

As with groundwater, Miami University did not investigate the Great Miami River in its site characterization study. However, there is other information available regarding the determination of past impact to the Great Miami River. Miller et al. have been collecting fish data from the Great Miami River since 1984. Electrofishing is conducted at specified locations both above and below the FEMP outfall (Figure 2-5). The goal of the sampling program is to determine changes in the health of the fish community between sampling sites on the river compared to past years. This is accomplished through an evaluation of fish species richness, diversity, and biomass. Over the 12-year period of monitoring (1984 - 1995), the Great Miami River fish community has shown an expected diversity with respect to habitat and water quantity. While changes in water quantity from year to year have influenced the fish communities, these changes have not been attributed to the FEMP, but rather upstream nutrient loading that results in hyper-eutrophic conditions (Miller 1993). A second goal of the annual electrofishing survey is to collect and prepare samples for laboratory analysis as part of the FEMP Radiological Environmental Monitoring program. Samples are analyzed for total uranium content to determine if the FEMP has had any impact on the individual species, between species or among the general fish population. Analytical results from this ongoing effort do not indicate that the FEMP has impacted fish found in the Great Miami River.

2.1.2.2 Future Impacts

Future remedial actions will involve the removal of the outfall from the FEMP to the Great Miami River (Figure 2-6). In addition, any soil at the outfall requiring cleanup will also be removed. It is anticipated that this will impact approximately four acres of the Great Miami River bank and the outfall line. Included within this impacted area is approximately 0.25 acres of riparian habitat along the bank of the Great Miami River.

2.2 Paddys Run Corridor

A summary of impacts to Paddys Run corridor is presented below and in Table 2-2. This section includes Paddys Run, drainage-ways into Paddys Run, and the associated riparian corridor that is found on either side of the stream.

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2.2.1 Past Impacts

A portion of the Paddys Run corridor has been impacted from past releases of contamination (as presented in Figure 1-~~3~~4) and several activities that resulted in the relocation of the stream bed. For the purposes of calculating impacts in this document, the width of the stream bed of Paddys Run was estimated to be 50 feet ~~wide~~ on average. (Note that the width of riparian corridor is more than 50 feet on average, but impacts have been limited to the stream itself and areas immediately east of the stream). Areas adjacent to the Waste Storage Area, Inactive Flyash Pile and South Field Areas have been impacted from past activities. Contamination and areas disturbed from past relocation overlap and are estimated to comprise approximately 5,700 feet of the Paddys Run corridor. Therefore, approximately 10 acres of Paddys Run have been impacted from past activities.

Several media were considered during the Sitewide Ecological Risk Assessment. Since Paddys Run is a primary land feature within this area, sediment and surface water were evaluated in addition to soil. The results are summarized on Table 2-2. For soil, uranium was the only COC found within the Paddys Run Corridor. As discussed in Section 1.2, there were no radiological risks to ecological receptors at the FEMP. Uranium was considered a COC based on its potential toxicity as a heavy metal.

An analysis of on-property sediment data revealed four COCs to ecological receptors; barium, cadmium, cyanide, and manganese. Off-property sediment data identified manganese as a COC.

For surface water, six contaminants were identified as COCs to ecological receptors. These COCs were aluminum, bis(2-ethylhexyl)phthalate, cadmium, Di-n-octyl phthalate, lead, and silver. Off-property, the COCs were lead, bis(2-ethylhexyl)phthalate, and Di-n-octyl phthalate. Of particular concern is lead, bis(2-ethylhexyl)phthalate, and Di-n-octyl phthalate due to the higher TQs and continued detection off-site.

Flora and Fauna

Trees, shrubs, and herbaceous vegetation were surveyed from June 1986 to August 1986. Herbs were sampled again in April 1987 and May 1987. For the Paddys Run corridor, Miami University reported that "the riparian communities lacked the typical large dominant sycamores, silver maples, and cottonwoods of a mature riparian system." This finding was attributed to the intermittent nature of Paddys Run and the historical management of the stream. The stream channel of Paddys Run has been

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altered twice in the past to mitigate erosion problems. Indeed, the riparian community was more diverse in the northern section of Paddys Run (RN1, Figure 2-7), where no channel alterations have occurred and water flow is present the entire year. Shrubs and herbs were found to be most diverse in the lower section of the Paddys Run corridor (RN 2, Figure 2-7), suggesting an earlier state of succession, along with possible impacts in the northern section due to cattle grazing (Facemire et al, 1990).

Miami University collected fish from Paddys Run in June 1986, as well as March 1987 and June 1987. Results of these surveys indicated that "Paddys Run appears to have a relatively diverse ichthyofauna in the area of stream above the K-65 storage tanks." This finding correlates with the intermittent nature of Paddys Run, which goes dry much of the year in the vicinity of the K-65 silos. Low species diversity was generally observed in the lower reaches of Paddys Run, Site 3 (Figure 2-7) also exhibited a reduced diversity in March 1987. Miami University stated that the reasons for the low diversity "were not known" but may have been attributable to runoff "or some other factors affecting habitat quality." To address this, the Sitewide Ecological Risk Assessment compared Paddys Run fish data from various sources spanning 35 years (Table 2-3). The data summarized in Table 2-3 suggest that the fish community in Paddys Run is diverse and stable. The variability that exists in the data can be attributed to the seasonal fluctuations of flow.

Miami University surveyed macroinvertebrates in November 1986 and December 1986 and again in February 1987. As with fish, upstream reaches of Paddys Run (Sites 1-4, Figure 2-7) showed greater densities and higher diversity than the lower reaches of Paddys Run (Sites 5-10, Figure 2-7). The researchers reported that "the most probable cause of the observed changes in the macroinvertebrate communities downstream of Site 4 was the dry period preceding sampling." In the discussion of the February 1987 sample period, Miami University concluded that Paddys Run macoinvertebrate data indicated "a clear indication of increasing environmental impact with distance from the stream source." The Sitewide Ecological Risk Assessment addressed this finding, by evaluating Miami University's community indices and comparing their data with other macroinvertebrate data for Paddys Run. The Sitewide Ecological Risk Assessment concluded that "the data collected in February 1987 represent an anomaly; measurements calculated from data collected before and after this period are higher than those based on the February samples" (Table 2-4).

Miami University surveyed the avifauna of the FEMP from June 1986 to July 1986, December 1986 to March 1987, and April 1987 to May 1987. The riparian corridor had the highest diversity of bird species at the site. Researchers concluded that "a diverse avifauna exists at the FMPC." However, it was noted that nighthawks and other insectivores were expected but missing. This finding is probably attributed to survey methods (i.e. the time of day and the time frame with respect to the breeding season). As shown on Table 2-5, other surveys have observed numerous insectivores (including nighthawks) at the FEMP.

As indicated on Table 2-5, the raptor population on the FEMP Site was determined to be essentially normal in the results of the Miami Study. A survey for raptors was conducted as part of the summer and winter surveys in 1986. However, the spring survey in 1987 focused only on migratory birds and did not look for raptors. The species that were identified were as expected, except for the Cooper's Hawk (which is rare in this area). The species absent on Table 2-5 were identified as rare or uncommon winter residents in Southwestern Ohio. In addition, the Miami Study concluded that suitable habitats did not exist on the FEMP for the owl species that were not found on the FEMP.

<u>Other Actions</u>

Paddys Run was relocated in 1962 to prevent the erosion of the waste pit area. The relocation of the stream had a short-term impact on the habitat in Paddys Run. Several Removal Actions have influenced impacts to the Paddys Run corridor in recent years. A summary of these Removal Actions and their impact (both positive and negative) is provided below. The Waste Pit Area Stormwater Runoff Control Removal Action, completed in July 1992, provided a system for the collection and treatment of potentially contaminated storm water runoff from the waste pit area to prevent it from reaching Paddys Run. The system is operational. A similarly-scoped Removal Action was conducted for a portion of the former production area. The Uncontrolled Production Area Runoff (Northeast) Removal Action was successful in collecting storm water runoff from perimeter areas of the former production area which were not draining into the storm water retention basins at the time.

The Inactive Flyash Pile Removal Action was conducted to install a long-term erosion control measure on the east bank of Paddys Run at the Inactive Flyash Pile. The ~~action consisted of adding rock to the~~ erosion control was a ~~rock~~ rip rap berm which was constructed during Phase I of the Time-Critical Removal Action ~~performed~~ in April and May of 1993. Phase II of this removal action ~~This action~~ increased the nominal height of the berm three feet to Elevation 540 feet MSL in critical areas. The added weight of the rock increased the forces resisting any slope failure and provided more stability. This rock also covered the exposed vertical soil face above Elevation 537 feet MSL to minimize erosion during high water levels. Stones were also placed along the toe of the berm in order to achieve a tumble-down effect of stone into eroded areas created by the stream at the base of the berm. This Removal Action had a negative impact to approximately 200 feet of Paddys Run due to stream habitat alteration.

2.2.2 Future Impacts

Anticipated future impacts include the excavation of the waste pits and associated regrading of the waste pit area resulting in the loss of approximately 13.2 acres of riparian habitat along Paddys Run (includes Sloan's crayfish habitat). Excavation and construction activities associated with the Inactive Flyash Pile will result in the loss of approximately 4.4 acres of early/mid-successional and riparian woodlands. The excavation of contaminated soil will result in the loss of approximately 16.5 acres of riparian habitat (includes Sloan's crayfish habitat). The total impacted riparian habitat is approximately 34 acres (Figure 2-8).

2.2.3 Residual Impacts

As identified on Figure 1-3, COCs at above BTV levels have been identified in the sediment and surface water of Paddys Run during past sampling events. At the conclusion of soil remediation, certification sampling that identifies any COCs that exceed FRLs within Paddys Run will remediated pursuant to the OU5 ROD. Any COCs exceeding BTVs will also be identified and addressed as part of post-remediation sampling (e.g., Integrated Environmental Monitoring Plan) as part of the methodology outlined in the NRRP and agreed upon by the FEMP NRTs. In addition, BTV exceedances that are identified during post-remediation sampling may be considered additional residual impacts and factored into the NRRP as determined appropriate by the FEMP NRTs.

2.3 Southern Pines and Waste Units

This section describes past and future anticipated impacts to the Southern Pines and Waste Units area. This area includes the southern pine plantation, the Inactive Flyash Pile, the South Field, the Active Flyash Pile, and adjacent riparian areas. Several separate areas have been included in this section, since they were originally considered as part of a single area within the Sitewide Ecological Risk Assessment (Figure 1-12).

2.3.1 Past Impacts

The areal extent of contamination, as determined for the preferred alternative in the OU5 RI/FS process, was used to determine past impacts to land within the Southern Pines and Waste Units area. There is no acreage within the southern pine plantation that was contaminated during production operations, as indicated by the OU5 RI/FS process (Figure 1-~~3~~4). The Inactive Flyash Pile and South Field constitute approximately 19.7 acres of land that has been contaminated by FEMP operations. Acreage for the other areas include approximately 10 acres of the Pilot Plant Drainage Ditch area, approximately 5.4 acres of soil underneath the Active Flyash Pile, and approximately 5.0 acres of riparian habitat along the Storm Sewer Outfall Ditch for a total of 40 acres of past impacts (Figure 1-~~3~~4).

The Sitewide Ecological Risk Assessment identified three COCs for soil; antimony, cadmium, and silver. For surface water, the COCs identified were aluminum and beryllium. In this instance, the COCs were considered a risk to terrestrial organisms that use the surface water as a drinking and/or bathing source (Table 2-6).

Flora and Fauna

During the 1986 and 1987 characterization of the FEMP, researchers at Miami University investigated two separate habitats within this area; the southern pine plantation and the Inactive Flyash Pile. As with other areas of the FEMP, various flora and fauna were surveyed. A summary of their findings is provided below.

As expected, the southern pine plantation ranked low with respect to tree diversity. There were no findings from researchers of expected species that were not present. Herbs were more diverse than expected. In 1986 and 1987, the Inactive Flyash Pile was not a radiologically controlled area, so it was surveyed by Miami University as a separate, distinct habitat. The researchers concluded that the area is primarily an old-field type habitat with lower expected diversity than later successional habitats (woodlots and riparian habitats).

Both the southern pine plantation and the reclaimed flyash pile showed lower diversities of birds when compared to other habitats on-property. This is attributed to habitat quality (old field habitat and introduced monoculture). See the previous discussion in Section 2.2 for Miami University's findings regarding avian species at the FEMP.

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Surveys for small mammals were conducted between July 1986 and August 1986. The species trapped were expected, but several species that were expected were not trapped. Furthermore, there appeared to be a disparity in the species caught in certain habitats. For instance, with the exception of one cottontail rabbit, short tail shrews were the only species captured within the reclaimed flyash pile. ~~On the other hand,~~ In addition, after 360 trap-nights of effort, only two individuals were captured within the three pastures. Researchers ~~did not offer an~~ did offer an explanation for these findings, stating that rabbit populations may be lower than surrounding areas due to predation and land management. Despite low catch rates for some species across the site, normal populations were found for the white footed mouse, meadow vole and chipmunk.

In some cases, low catch rates were identified in certain areas such as those stated for the meadow jumping mouse and house mouse. Overall, the Miami Study stated that small mammal populations were essentially normal for the site and that lower population levels were likely due to land management and/or population cycles.

In addition, as discussed in Section 2.2.1, Raptor populations on the FEMP were determined to be essentially normal. Therefore, it is assumed that prey species (e.g., small mammals) are adequate to support the raptor population on site. ~~However, it seems that apparent discrepancies between what was expected and what was caught could be explained by sampling methods.~~

~~Small mammal sampling is dependent on many variables that add to the uncertainty of the results. For example, the Methods section did not include information regarding bait, which could influence the kinds of species that would be caught. These uncertainties became evident when Miami University reported that while only one chipmunk was captured, a researcher personally saw several chipmunks within the riparian area. Therefore, it is the position of DOE FEMP that due to sample bias, the small mammal population as reported by Miami University is not representative of the FEMP. It is DOE FEMP's position, based on field observation of small mammals and considering the diverse raptor population on the site that there is normal population levels and diversity of small mammals on the FEMP.~~

Other Actions

The Active Flyash Pile Controls Removal Action was conducted to mitigate potential wind and water erosion at the Active Flyash Pile. Minor grading and compaction were conducted, a silt fence was installed around the base of the pile, wind barriers were erected, and a chemical spray was applied to the surface of the flyash pile to mitigate wind erosion and provide surface stabilization. The pile is now inactive and will no longer receive new ash deposits. The potential use of flyash as an additive to soil for use in backfill, structural fill, and slope stability applications was also investigated. This Removal Action reduced the impact from runoff into the adjacent riparian and stream habitat and was completed in June 1992. In addition, 5 acres of the Southern Pines were disturbed due to clearing to support the meteorological tower and other projects.

2.3.2 Future Impacts

Anticipated future impacts include the excavation and construction activities at the Inactive Flyash Pile, resulting in the loss of approximately 4.7 acres of old field habitat. In addition, remediation of the South Field and Pilot Plant Drainage Ditch would result in the loss of approximately 13.0 acres of old field habitat, 7.5 acres of woodland and 0.6 acres of wetlands, respectively (Figure 2-8).

2.4 Northern Woodlot and Northern Pine Plantation

This section describes past impacts and anticipated future impacts to the northern woodlot area and the northern pine plantation. A major feature of the northern woodlot is the 26 acre forested wetland. Early and mid-successional woodlands and old field habitats are also found within the northern woodlot.

2.4.1 Past Impacts

Using the areal extent of contamination to determine past impact, the acreage impacted within the northern woodlot is approximately 2.~~2~~6 acres. For the northern pine plantation, approximately 1.4 acres of land have been impacted. As shown on Figure 1-~~3~~4, minor contamination is found within these areas.

Results from the Sitewide Ecological Risk Assessment are summarized on Table 2-7. For soil in the northern woodlot, seven COCs were identified. These were cadmium, molybdenum, zinc, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and chrysene. As shown on Figure 1-~~3~~4, many of these COCs were concentrated around the Fire Training Facility. Zinc was identified as a concern in the northern woodland. However this was based on one sample exceeding the BTV in the area of the fire training facility which is not part of the northern woodlands. Soil COCs within the northern pine plantation were determined to be aluminum, manganese, and molybdenum. Aluminum and molybdenum appear to have scattered results above the BTV and do not follow any patterns of contamination seen in other constituents. The interpretation of the risk associated with the levels of aluminum is further complicated by the range of background levels. Both surface (11,900 mg/kg) and subsurface (16,100 mg/kg) soil concentrations are within the 95th percentile of background levels as established in the OU5 RI/FS which are greater than the BTV (10,103 mg/kg). Thus, aluminum appears to be part of natural background. COCs for surface water in the northern woodlot were identified as aluminum, cadmium, mercury, and uranium (as a heavy metal). As with the southern pines and waste units area, the risk from surface water was attributed to terrestrial organisms using water as a drinking and/or bathing source.

Flora and Fauna

In the Miami University characterization study, several findings were made within the northern woodlot and northern pine plantation. The northern woodlots were some of the more diverse habitats with respect to trees, shrubs, and herbs. Woodlot No. 3 was the most mature of the three sections (Figure 2-7). The northern pine plantation, on the other hand, was much less diverse. This would be expected since the northern pine plantation is an introduced monoculture.

The northern woodlot exhibited varying degrees of diversity with respect to avifauna, while the northern pine plantation was less diverse than all habitats except the grasslands. One finding from the Miami University Characterization Report regarding birds in several areas, including the northern pine plantation, was the suppressed growth of robin and dove nestlings. Doves from the northern pine plantation and robins from the southern pine plantation showed statistically significant differences in several growth parameters when compared to off-property locations. Researchers postulated that "species differences in suppressed growth could be attributable to species specific differences in diet or to potential on-site physiological stressors, including differences in accumulating radiological or chemical loads." To investigate this further, several follow-up studies were conducted. Robins were evaluated because they appeared more severely stressed.

The 1991 follow-up study found that while FEMP robins produced normal-sized clutches, normal-sized eggs, and fledged a normal percentage of young, nestlings exhibited suppressed growth in four of five prefledgling growth parameters (Osborne 1991). The second follow-up study in 1992 showed that FEMP robins still exhibited suppressed growth in two of four parameters measured (Osborne 1992). Heavy metals and pesticides were evaluated as a stressor through the soil-earthworm pathway. No

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metals or pesticides were detected in FEMP soil and earthworm samples. Based on the results of this final study, the researchers concluded that the growth suppression of robin nestlings at the FEMP is related to land management practices that affect both food availability and the quality of diet (Osborne 1992). The previous discussion in Section 2.2 provides a critique of Miami University's avifauna surveys. See Section 2.3 for discussion of small mammal surveys.

Other Actions

Removal Actions have influenced impacts to the northern woodlot. The Fire Training Facility Removal Action removed contamination associated with the Fire Training Facility (Building 63) structures, equipment, surficial soils, and surface water. Prior to dismantling and removal activities, all liquids were removed from the open top tank, skid tank pond, the sump, and the horizontal pressure vessel end piece. These liquids were treated prior to disposal. Each of these structures, in addition to the block building and asphalt pad, were demolished and removed for disposal. As stated earlier, most of the COCs from the Sitewide Ecological Risk Assessment associated with the northern woodlot were concentrated around the Fire Training Facility. This Removal Action, therefore, has reduced much of the impact to ecological receptors within the northern woodlot.

There are some soil parameters identified through the Sitewide Ecological Risk Assessment that are not anticipated to be excavated (Figure 2-9). Based on the approach set forth in Section 1.2.3, these COCs are considered residual impacts at this time. This evaluation may be revised at a later date, depending on the results of the certification process.

2.4.2 Future Impacts

Anticipated future impacts for the northern woodlot and northern pine plantation include construction of the buffer area associated with the on-site disposal facility resulting in the loss of approximately 40 acres of the northern pine plantation (Figure 2-8).

2.4.3 Residual Impacts

It is anticipated that residual impacts may occur due to the continued presence of ecological COCs at above BTV concentrations in approximately 5 acres of the northern woodlot.

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2.5 Introduced Grasslands

Past impacts and anticipated future impacts to grasslands at the FEMP are presented below. As Figure 1-~~1~~2 shows, the grassland area encompasses the entire eastern portion of the FEMP. The On-Site Disposal Facility (OSDF) will be constructed within this area.

2.5.1 Past Impacts

The areal extent of contamination as determined in the OU5 RI/FS process reveals a past impact to soil of approximately 93~~.3~~ acres (Figure 1-~~3~~4).

The Sitewide Ecological Risk Assessment showed 13 COCs for soil in the grasslands area. These COCs were aluminum, antimony, lead, manganese, molybdenum, uranium (as a heavy metal), benzo(g,h,i)perylene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3 cd)pyrene. Most of these constituents are only found in localized areas which are known and expected to be contaminated with multiple constituents, such as the Sewage Treatment Plant. Aluminum and molybdenum concentrations above the BTV appear to have scattered results and do not follow patterns of contamination as seen in other constituents. Again, the interpretation of the risk associated with the levels of aluminum is further complicated by the range of background levels. The polynuclear aromatic hydrocarbons (PAHs), lead, and uranium are COCs exhibiting defined areas of contamination, and thus are considered to have the greatest impact to ecological receptors from exposure to soil within the grasslands area, the PAHs are generally focused around the Sewage Treatment Plant. Uranium will be addressed through the FRL-driven soil remediation process, since the BTV is a higher concentration than the FRL. Lead is a concentrated contaminant in the trap firing range. It is expected that the soil remediation will also mitigate ecological risk associated with the PAHs and lead.

For surface water (as a source of drinking water for terrestrial organisms), the COCs were aluminum and beryllium. Two COCs, manganese and lead, were identified for off-property soil (Table 2-8).

Flora and Fauna

The Miami University characterization study revealed typical diversity for introduced grasslands, both grazed and ungrazed. Refer to Section 2.3 for the discussion regarding the surveys for small mammals.

Other Actions

The Contaminated Soils Adjacent to Sewage Treatment Plant Incinerator Removal Action was undertaken to prevent any potential contaminant migration in soils near the inactive Sewage Treatment Plant incinerator. This action involved the characterization, removal, containerization, storage, and disposal of soils with elevated uranium levels in the vicinity of an out-of-service solid waste incinerator at the Sewage Treatment Plant. Excavation of contaminated soils and post-excavation sampling activities were completed on October 16, 1992. As with the Fire Training Facility, many of the COCs identified in the Sitewide Ecological Risk Assessment were located near the Sewage Treatment Plant. Therefore, this Removal Action greatly reduced risks to terrestrial organisms within the grassland area. Excavation did result in a negative impact to approximately 10 acres of an off-property woodlot adjacent to the Sewage Treatment Plant.

2.5.2 Future Impacts

Future impacts include the construction of the OSDF and associated buffer area resulting in the loss of approximately 86 acres of introduced grassland habitat. Excavation and construction activities associated with the Vitrification Plant would result in the loss of approximately 2.5 acres of grassland habitat. The excavation of contaminated soil would result in the loss of approximately 115 acres of grassland habitat and 0.6 acres of wetlands. Total impacted introduced grassland is approximately 20~~3.5~~4 acres (Figure 2-~~6~~8).

2.6 Waste Storage Area

2.6.1 Past Impacts

Past impacts associated with the Waste Storage Area include of approximately 37 acres of land attributed to the areal extent of contamination ~~and~~ which includes 5 acres of on-property wetlands.

The Sitewide Ecological Risk Assessment and the Miami University characterization survey did not investigate habitats within the Waste Storage Area. Also, Miami University did not evaluate wetlands specifically in its report. However, Miami University did address population genetics of spring peeper treefrogs. Electrophoretic analysis of select FEMP plant and animal species, including spring peeper treefrogs was conducted. One finding of this research was that spring peeper tadpoles and frogs collected from a wetland near the waste pits exhibited a null allele that was not present in an off-property control population. This null allele was not found in the heterozygous condition. The researcher suggested that this finding could be from some sort of on-site chemical or radiological

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stress. A follow-up study was conducted in 1991 and the results showed that the null allele was present in off-property spring peepers up to 20 km away (Guttman 1991). A third study in 1992 looked at spring peepers as far away as Wheeling, West Virginia and still found the presence of the null allele (Guttman 1992). Also, the original off-property control was re-evaluated and the null allele was determined to be present in that sample as well. Therefore, the researcher concluded that the presence of the null allele in spring peeper frogs and tadpoles is not attributable to any kind of on-property chemical or radiological stress, but rather a regional phenomenon that reaches across the southern half of Ohio.

2.7 Former Production Area

2.7.1 Past Impacts

Past impacts within the former production area include approximately 136 acres of land attributed to the areal extent of contamination and ~~3.8~~ 4.0 acres of on-property wetlands.

The Sitewide Ecological Risk Assessment and the Miami University characterization survey did not investigate habitats within the former production area, since this area is characterized as an industrial area with limited quality habitat due to land management practices.

3.0 SUMMARY

Impacts to natural resources at the FEMP were presented using existing information which characterizes the interaction of the ecology and past and anticipated future activities of the site. Past impacts were derived from a combination of process knowledge, remedial investigation studies and ecological reports. Anticipated future impacts were derived from Remedial Investigations, Feasibility Studies, Records of Decisions, and available information from remedial design. The impacts presented in this document will be evaluated by the Natural Resource Trustees and used to determine appropriate restoration measures.

The following ~~summary lists~~ summarizes past, future, and residual impacts for each area:

- 172 acres of groundwater impacts.
- ~~632~~ 618 acres of past and anticipated future impacts to various areas of the site.

Table 3-1 presents an area-by-area summary of past and future impacts.

Areas identified as past impacts with respect to the areal extent of contamination were not counted again as future impacts. Past impacts were identified when a release of a hazardous substance resulted in the contamination and/or physical disturbance of portions of the site. It is anticipated that the identified past impact areas, with the exception of groundwater, will be physically disturbed during remediation. Future impacts are those areas that will be physically disturbed from remedial activities and do not include areas of past impact (e.g., construction of the on-site disposal facility, excavation of borrow area).

The purpose of this assessment is to provide reasonable inferences of past impacts and anticipated future impacts from remedial activities. Upon concurrence with the NRIA, the Trustees will determine appropriate restoration activities to compensate for natural resource impacts. These restoration activities will be developed within a restoration plan which will be integrated ~~into~~ with the remedial design and remedial action documentation being prepared at the FEMP pursuant to CERCLA.

SUMMARY OF KEY NATURAL RESOURCE IMPACTS

Great Miami Aquifer

Past Impacts

- 172 acres of quantified groundwater impact (20 μg/l) to the Great Miami Aquifer (Figure 2-1)
- 96 acres of perched groundwater impacts in Study Areas C, E, F & G

Future Impacts

- 5.0×10^{10} gallons of groundwater anticipated to be pumped from the Great Miami Aquifer due to remedial activities
- Up to 15 acres of additional off-property impacted due to plume migration

Residual Impacts

- Approximately 11~~83~~98 acres of above background (~~5~~3ug/l) uranium groundwater plume will remain after remedial action is complete (Figure ~~1-4~~ 2-3)

Other Information

- Removal Actions and the Public Water Supply Project have mitigated impacts and/or service losses to the Great Miami Aquifer

Great Miami River

Past Impacts

- Slight increases (less than two times background) in Great Miami River surface water uranium concentrations downstream of the FEMP (Figure 2-~~3~~4)
- Elevated levels of aluminum, beryllium, zinc, VOAs, and semi-VOAs detected in sediments, but difficult to attribute specifically to the FEMP (Figure 2-~~3~~4)
- 12 COCs found in sediment and/or surface water in the Great Miami River (Figure 2-3, Table 2-1). Again, these are difficult to attribute specifically to the FEMP

Future Impacts

- Three acres of impact anticipated for the Great Miami River due to remedial activities, including 0.25 acres of riparian habitat (Figure 2-~~5~~6)

Residual Impacts

Not Applicable

Other Information

- Removal Actions have mitigated impacts and/or service losses to Great Miami River
- Fish data from 1984 to present reveal that the FEMP has not impacted fish communities upstream or downstream of the FEMP

<u>Paddys Run Corridor</u>

Past Impacts

- 10 acres of quantified soil impact to the Riparian Corridor (Figure 1-~~3~~4)
- Paddys Run Relocation in 1962.
- 10 ecological COCs found in soil, sediment, and/or surface water (Figure 1-~~3~~4, Table 2-2)

Future Impacts

- 34 acres of impact anticipated due to remedial activities (Figure 2-~~6~~8)

Other Information

- Riparian flora is more diverse in the upstream section of Paddys Run, possibly because of stream alterations downstream
- Paddys Run fish community is diverse and stable, with variabilities occurring because of seasonal fluctuations in flow
- Paddys Run macroinvertebrates show higher diversity upstream, which is attributed to the intermittent nature of the stream
- Riparian corridor has high avian diversity
- Removal Actions have mitigated and/or attributed to impacts and/or service losses in the Paddys Run corridor

Southern Pines and Waste Units

Past Impacts

- ~~20~~ 40 Acres of quantified soil impact to the Southern Pines and other Waste Units (Figure 1-~~3~~4)

- Three ecological COCs found in soil or surface water (Figure 1-3, Table 2-6)

Future Impacts

- 17 acres of impact anticipated due to remedial activities of the waste units (i.e., Inactive Flyash Pile, South Field; (Figure 2-~~6~~8)

Other Information

- Flora and fauna diversities were expected with respect to habitat quality (old field and introduced monoculture)
- Removal Actions have mitigated and/or attributed to impacts and/or service losses
- Approximately 5 acres of the Southern Pines impacted from project clearing activity

Northern Woodlot and North Pine Plantation

Past Impacts

- Four acres of quantified soil impact to the Northern Woodlot and North Pine Plantation (Figure 1-~~3~~4)

- 11 COCs found in soil and surface water, most of which concentrated in the vicinity of the Fire Training Facility (Figure 1-~~3~~4, Table 2-7)

Future Impacts

- 40 acres of impact anticipated due to remedial activities (Figure 2-~~6~~8)

Residual Impacts

- Five acres of residual impact anticipated due to the continued presence of potential ecological COCs at above BTV concentration (Figure 2-~~8~~9)

Other Information

- Diverse flora and fauna exist in the Northern Woodlots. The diversity of the North Pine Plantation is as expected (introduced monoculture)

- Impacts to robins attributed to land management practices

- Removal Actions have mitigated impacts and/or service losses

Introduced Grasslands

Past Impacts

- 93 acres of quantified soil impact to the Grasslands (Figure 1-~~3~~4)
- 10 acres of off-property woodlot clearing during removal action
- 13 ecological COCs found in soil and surface water, most of which concentrated around the Sewage Treatment Plant (Figure 1-~~3~~4, Table 2-8)

Future Impacts

- 204 acres of impact anticipated due to remedial activities (Figure 2-~~6~~8)

Other Information

- Grasslands exhibited typical diversity
- Removal Actions have mitigated and/or attributed to impacts and/or service losses

Waste Storage/Production Area

Past Impacts

- 173 acres of quantified soil impact to the Waste Storage and Production Area (Figure 1-~~3~~4)

Future Impacts

- Nine acres of wetlands filled due to remedial activities

Other Information

- Treefrog null allele attributed to regional conditions, not the FEMP

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TABLE 1

ECO-RISK DATA FOR GREAT MIAMI RIVER

	Upstream of Outfall	Between Outfall and Paddys Run	Confluence With Paddys Run	Benchmark Toxicity Value
Barium	-	130^{A}	228^{B} 89^{A}	145^{B} 40^{A}
Iron	-	$19,800^{A}$	-	17,000
Lead	-	39.7^{A}	44.2^{B}	$35^{A}/30^{B}$
Phenathrene	-	2200^{A}	-	6.3^{A}
Manganese	-	729^{A}	561^{B} 667^{A}	300^{A} 98^{B}
Zinc	Not Analyzed	90^{A}	171^{A}	120
Mercury	0.7^{BC}	-	-	0.2^{BC}
Ammonia	1900^{B}	-	-	1,000
Aluminum	Not Analyzed (Surface Water)	674^{BC}	$19,100^{B}$ $19,100^{C}$	87^{BC}
Cyanide	Not Analyzed	16.8^{B}	21.4^{B}	12
Cadmium	-	5.3^{BC}	$18^{B}/18^{C}$	3.5^{B} 5^{C}
Bis (2) Phthalate	Not Analyzed (Surface Water)	-	160^{BC}	8.4^{B} 18^{C}
Beryllium	Not Analyzed (Surface Water)	7.70^{C}		4.0

A - Sediment (mg/kg)
B - Surface Water (ug/L)
C - Terrestrial Organisms (ug/L)

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TABLE 2-2

ECO-RISK DATA FOR PADDYS RUN

	SOIL	SEDIMENT	SURFACE WATER	DRINKING WATER	BENCHMARK TOXICITY VALUE
Uranium	254[A]	-	-	-	230[C]
Barium	-	58.7[A]	-	-	40[D]
Cadmium	-	5.5[A]	5.0[A]	5.0[A]	3.5[F] 5.0[DF]
Cyanide	-	0.49[A]	-	-	0.10[D]
Manganese	-	1070[A] 499[B]	-	-	300[D]
Bis (2) Phthalate	-	-	40[A]/22[B]	40[A] 22[B]	8.4[E] 18[F]
Di-n-Octyl Phthalate	-	-	52[A]/89[B]	52[A] 89[B]	47.7[EF]
Lead	-	-	156[A]/69.7[B]	156[A] 69.7[B]	30[E] 50[F]
Silver	-	-	4.0[A]	-	1.3[E]
Aluminum	-	-	145[A]	145[A]	87[EF]

A - On-property
B - Off-property
C - Soil (mg/kg)
D - Sediment (mg/kg)
E - Surface Water (mg/l)
F - Terrestrial Organisms (mg/l)

Table 2-3

PADDYS RUN FISH DATA COMPARISON

Scientific Name	Common Name	Area[f] 1	2	3	4	5
Clupeidae (Herring Family)						
Dorosoma cepedianum	gizzard shad					c
Cyprinidae (Minnow Family)						
Campostoma anomalum	central stoneroller	c	a,b,c,d,e	a,b	b,c,d	b,d,c
Cyprinella spiloptera	spotfin shiner	c	b,c	b	c	b,c
Cyprinella whipplei	steelcolor shiner			a		
Luxilus chrysocephalus	striped shiner		b,e	a,b		
Luxilus cornutus	common shiner	c	c,d		c,d	d,c
Lythrusus ardens	rosefin shiner	c	a,b,c	a,b		b
Lythrurus umbratilis	redfin shiner		d		d	d
Notropis atherinoides	emerald shiner		b			c
Notropis boops	bigeye shiner					c
Notropis buccattus	silverjaw minnow	c	a,b,c,d,e	a,b		b,d
Notropis stramineus	sand shiner		b,c			
Phenacobius mirabilis	suckermouth minnow					b
Phoxinus erythrogaster	southern redbelly dace		c,d	b	d	d
Pimephales notatus	bluntnose minnow		a,b,c,d,e	a,b	c,d	b,c,d
Pimephales promelas	fathead minnow	c	c,d		d	
Rhinichthys atratulus	blacknose dace		a,b,c,d	b	d	b,d
Semotilus atromaculatus	creek chub		a,b,d,e	a,b	b,d	b,d
Catastomidae (Sucker Family)						
Catastomus commersoni	white sucker		a,b,c,d,e	a	d	b,d
Centrarchidae (Sunfish Family)						
Lepomis cyanellus	green sunfish	c	c,d		d	d
Lepomis macrochirus	bluegill	c	c			c
Lepomis megalotis	longear sunfish		c,d			
Lepomis spp.	sunfish hybrid			b	b	b
Micropterus salmoides	largemouth bass	c	c			
Micropterus dolomieui	smallmouth bass					d
Ictaluridae (Catfish Family)						
Ameiurus natalis	yellow bullhead		d			

Scientific Name	Common Name	Area[f] 1	2	3	4	5
Percidae (Darter Family)						
Etheostoma caeruleum	rainbow darter					b
Etheostoma flabellare	fantail darter	c	a,b,c,d,e	a,b	d	b
Etheostoma nigrum	johnny darter		a,b,c,d,e	a,b	d	b,d
Etheostoma spectabile	orangethroat darter		a,b,c,d,e	a,b	b,d	b,d
Cottidae (Sculpin Family)						
Cottus bairdi	mottled sculpin		d		d	d
Number of Species Observed (All Reports)		10	24	15	16	24

a: Facemire June-August 1986
b: Facemire January-March 1987
c: Bauer December 1972 - October 1973
d: Tarzwell 1952
e: Pomeroy 1977

[f]Locations sampled in various studies were grouped by "Area" on Paddy's Run. These sampling locations were grouped as follows:

Area 1 = Bauer's station 1
Area 2 = Bauer's stations 2 and 3, Tarzwell's station 1, Facemire's stations 1 and 2, and Pomeroy's only sampling station
Area 3 = Facemire's stations 3, 4, 5, 6, 7 (Flow typically intermittent)
Area 4 = Facemire's station 8, 9, 10; Bauer's station 4; and Tarzwell's station 2 (Flow typically intermittent)
Area 5 = Bauer's stations 5 and 6, Facemire's station 11, and Tarzwell's station 3 (Flow typically intermittent)

TABLE 2-4

PADDYS RUN MACROINVERTEBRATE DATA COMPARISON

Station	Study						
	Pomeroy July 1977[a]	Facemire June 1986[b]	Facemire Mar./June 1987[b]	RI/FS May/June 1989[c]	RI/FS Nov./Dec. 1989[c]	RI/FS Mar./May 1990[c]	RI/FS June/Aug. 1990[c]
SHANNON DIVERSITY							
PR1		3.2	0.97				
PR2	1.39	2.06		2.29	3.24	3.5	3.3
PR3		2.4	0.43	2.54	2.43	2.99	2.81
PR4		1.9					
PR5		1.69	0.21	1.06	1.06	3.01	3.11
PR6		2.68		0.55	1.04	3.31	no data
PR7		2.02					
PR8		1.8					
PR9		2.63		1.43	NA	3.33	no data
PR10		1.96					
PR11			0.66				
SIMPSON DIVERSITY							
PR1	0.4	0.844	0.744				
PR2		0.653		0.75	0.86	0.88	0.87
PR3		0.677	0.114	0.77	0.77	0.81	0.8
PR4		0.591					
PR5		0.599	0.043	0.28	0.31	0.8	0.85
PR6		0.777		0.15	0.36	0.87	no data
PR7		0.6					
PR8		0.474					
PR9		0.794		0.5	NA	0.85	no data
PR10		0.623					
PR11			0.156				

Station	Study						
	Pomeroy July 1977[a]	Facemire June 1986[b]	Facemire Mar./June 1987[b]	RI/FS May/June 1989[c]	RI/FS Nov./Dec. 1989[c]	RI/FS Mar./May 1990[c]	RI/FS June/Aug. 1990[c]
SIMPSON DOMINANCE							
PR1	0.6	0.156	0.256				
PR2		0.347		0.25	0.14	0.12	0.13
PR3		0.323	0.886	0.23	0.22	0.19	0.2
PR4		0.409					
PR5		0.401	0.956	0.71	0.69	0.2	0.15
PR6		0.222		0.84	0.64	0.13	no data
PR7		0.399					
PR8		0.526					
PR9		0.206		0.5	NA	0.15	no data
PR10		0.377					
PR11			0.844				
PIELOU'S EVENESS							
PR1	0.37	0.741	0.218				
PR2		0.484		0.82	0.8	0.81	0.79
PR3		0.556	0.114	0.8	0.73	0.66	0.72
PR4		0.499					
PR5		0.729	0.062	0.33	0.35	0.7	0.79
PR6		0.725		0.24	0.52	0.75	no data
PR7		0.583					
PR8		0.431					
PR9		0.76		0.55	NA	0.77	no data

TABLE 2-4 (continued)

PADDYS RUN MACROINVERTEBRATE DATA COMPARISON

Station	Study						
	Pomeroy July 1977[a]	Facemire June 1986[b]	Facemire Mar./June 1987[b]	RI/FS May/June 1989[c]	RI/FS Nov./Dec. 1989[c]	RI/FS Mar./May 1990[c]	RI/FS June/Aug. 1990[c]
DENSITY							
PR1		2939.5	4846.1				
PR2	4339.16	5023.5		100	240	568.9	577.2
PR3		5184.7	9077.6	151.1	184.4	773.3	586.7
PR4		3391.7					
PR5		55.1	6138.6	173.3	217.8	457.8	542.2
PR6		623.3		295.6	33.3	557.8	no data
PR7		308.1					
PR8		4158					
PR9		351.1		162.2	2.2	955.6	no data
PR10		330.1					
PR11			9163.1				

[a]Pomeroy 1977
[b]Facemire et al. 1990
[c]DOE 1992a

TABLE 2-5

AVIAN SPECIES DATA COMPARISON

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)	Study Dates			
			Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
Blue-winged Warbler	C	I and FG				x
Northern Parula Warbler	U	I and FG				
Yellow Warbler	C	I and FG		x		
Cerulean Warbler	C	I and FG				
Yellow-rumped Warbler	U	I and FG				x
Black-throated Green Warbler	C	I and FG				x
Yellow-throated Warbler	U	I and FG				
Blackpoll Warbler	R	I and FG				x
Prairie Warbler	U	I and FG				
Ovenbird	U					
Louisiana Waterthrush	C	I		x		
Northern Waterthrush	R	I				x
Kentucky Warbler	C	I				
Mourning Warbler	R	I				x
Common Yellowthroat	C	I and FG	x	x		
Yellow-breasted Chat	C	I and FG	x	x		
Hooded Warbler	R	I and FG				
American Redstart	U	I and FG				x
House Sparrow	A		x	x	x	
Eastern Meadowlark	A		x	x	x	
Red-winged Blackbird	A		x	x	x	
Common Grackle	A		x	x		
Brown-headed Cowbird	C		x	x		
Orchard Oriole	U	I and FG	x	x		
Northern Oriole	C	I and FG		x		
Scarlet Tanager	U	I and FG	x	x		
Summer Tanager	U	I and FG		x		
Cardinal	A		x	x	x	
Rose-breasted Grosbeak	U			x		x
Indigo Bunting	A		x	x		
Evening Grosbeak	I					
Purple Finch	U					
Pine Siskin	I					

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Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)	Study Dates Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
American Goldfinch	A		x	x	x	
Red Crossbill	I					
Rufous-sided Towhee	C		x	x	x	
Savannah Sparrow	U		x	x		
Grasshopper Sparrow	U		x	x		
Henslow's Sparrow	R					
Dark-eyed Junco	A				x	
Tree Sparrow	U				x	
Chipping Sparrow	C			x		
Field Sparrow	A		x	x		
White-crowned Sparrow	U					
White-throated Sparrow	A				x	
Fox Sparrow	R					
Swamp Sparrow	U					x
Song Sparrow	C		x	x	x	
Great blue heron	U			x		
Green Heron	C		x	x		
Canada Goose	C					
Mallard	C			x		
Black Duck	C					
Wood Duck	C			x		
Common Goldeneye	U					
Oldsquaw	R					
Turkey Vulture	C			x		
Black Vulture	R					
Sharp-shinned Hawk	R					
Cooper's Hawk	U			x	x	
Red-tailed Hawk	C		x	x	x	
Red-shouldered Hawk	U				x	
Broad-winged Hawk	U					
Rough-legged Hawk	R					
Marsh Hawk	U			x		
American Kestrel	C			x	x	
Bobwhite	C		x	x	x	
Killdeer	C	I	x	x	x	
American Woodcock	U			x		

TABLE 2-5 (continued)

AVIAN SPECIES DATA COMPARISON

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)	Study Dates: Summer 1977[b]	Study Dates: Summer 1986[c]	Study Dates: Winter 1986[d]	Study Dates: Spring 1987[e]
Spotted Sandpiper	C			x		
Solitary Sandpiper	U			x		x
Herring Gull	C					
Ring-billed Gull	U					
Rock Dove	A			x		
Mourning Dove	A		x	x	x	
Yellow-billed Cuckoo	C	I and FG	x	x		
Black-billed Cuckoo	U	I and FG		x		
Barn Owl	R					
Screech Owl	C			x	x	
Great Horned Owl	C			x	x	
Snowy Owl	I					
Barred Owl	C					
Long-eared Owl	R					
Short-eared Owl	R					
Saw-whet Owl	U					
Common Nighthawk	C	I	x			
Chimney Swift	A	I	x	x		
Belted Kingfisher	C		x	x	x	
Ruby-throated Hummingbird	C	I		x		
Common Flicker	C	I	x	x	x	
Pileated Woodpecker	U	I		x	x	
Red-bellied Woodpecker	C	I	x	x	x	
Red-headed Woodpecker	R	I		x		
Yellow-bellied Sapsucker	U	I				
Hairy Woodpecker	U	I		x	x	
Downy Woodpecker	A	I	x	x	x	
Eastern Kingbird	U	I		x		
Great Crested Flycatcher	C	I		x		
Eastern Phoebe	C	I		x		
Willow Flycatcher		I		x		
Arcadian Flycatcher	C	I		x		
Alder Flycatcher	U	I				

TABLE 2-5 (continued)

AVIAN SPECIES DATA COMPARISON

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)	Study Dates Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
Eastern wood Pewee	C	I	x	x		
Horned Lark	U	I				
Bank Swallow	U	I				
Rough-winged Swallow	U	I	x	x		
Barn Swallow	C	I	x	x		
Purple Martin	C	I		x		
Blue Jay	A		x	x	x	
Common Crow	A		x	x	x	
Carolina Chickadee	A	I and FG	x	x	x	
Tufted Titmouse	A	I and FG	x	x	x	
White-breasted Nuthatch	C	I		x	x	
Red-breasted Nuthatch	R	I				
Brown Creeper	U	I			x	
House Wren	C	I		x		
Winter Wren	R	I				
Carolina Wren	C	I		x	x	
Mockingbird	C	I	x	x	x	
Gray Catbird	C	I	x	x		
Brown Thrasher	C	I		x		
American Robin	A		x	x	x	
Wood Thrush	C	I	x	x		
Eastern Bluebird	U	I		x	x	
Blue-gray Gnatcatcher	C	I and FG	x	x		
Golden-crowned Kinglet	C	I and FG			x	
Ruby-crowned Kinglet	U	I and FG				
Cedar Waxwing	U			x		
Loggerhead Shrike	R					
Starling	A		x	x	x	
White-eyed Vireo	C	I and FG		x		
Yellow-throated Vireo	U	I and FG				
Solitary Vireo	U	I and FG				x
Red-eyed Vireo	A	I and FG	x	x		
Philadelphia Vireo	R	I and FG		x		

TABLE 2-5 (continued)

AVIAN SPECIES DATA COMPARISON

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)	Study Dates: Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
Warbling Vireo	U	I and FG		x		
Prothonotary Warbler	R	I and FG				
Black-and-white Warbler	C	I		x		
Tennessee Warbler	C	I and FG		x		x
Worm-eating Warbler	R					

[a]Species list derived from CNC (1978) and includes birds which regularly nest within the area and those expected during the winter months. The list also includes several unexpected species observed during one or more of the studies.

[b]Observed June 27 - 28, 1977 (Pomeroy et al. 1977).
[c]Observed June 25 - July 25, 1986 (Facemire et al. 1990).
[d]Observed December 5, 1986 - March 6, 1987 (Facemire et al. 1990).
[e]Observed April - May 1987 (Facemire et al. 1990).

[f]Abbreviations:
A = Abundant (may be seen more than 75% of the time in the proper habitat and at the right time of the year)
C = Common (may be seen more than 50% of the time)
U = Uncommon (may be seen between 10% and 50% of the time)
R = Rare (may be seen 10% or less of the time)
I = Irregular (occur in varying numbers from year to year, and in some years may not appear at all) (CNC 1978)

TABLE 2-6

ECO-RISK DATA FOR SOUTH PINES AND WASTE UNITS

	SOIL*	DRINKING WATER	BENCHMARK TOXICITY VALUE
Antimony	29.5	-	10*
Cadmium	5.8	-	5*
Silver	10.3	-	10*
Aluminum	-	1830†	87†
Beryllium	-	66†	4†

† Concentrations in ug/L
*Concentrations in mg/kg

TABLE [illegible]-7

ECO-RISK DATA FOR NORTH PINES AND WOODLOTS

	SOIL* - WOODLOT	DRINKING WATER † WOODLOT	SOIL* - PINES	BENCHMARK
Cadmium	5.90	6.30	-	5[AB]
Molybdenum	11.7	-	12.4	10[A]
Zinc	707	-	-	500[A]
Benzo (a) Anthracene	2.10	-	-	1[A]
Benzo (b) Fluorathane	2.10	-	-	1[A]
Chrysene	2.10	-	-	1[A]
Aluminum	-	232	10,700	10,103[A]/ 87[B]
Mercury	-	0.6	-	0.2[B]
Uranium	-	944	-	890[B]
Manganese	-	-	1530	1500[A]
Benzo (a) Pyrene	1.60	-	-	1[A]

A - Soils (mg/kg)
B - Terrestrial Organisms (ug/l)

* Concentrations in mg/kg
† Concentrations in mg/l

TABLE [illegible]8

ECO-RISK DATA FOR GRASSLANDS

	SOIL	DRINKING WATER	OFF-PROPERTY SOIL	BENCHMARK TOXICITY VALUE
Aluminum	25,700	1830*	-	10,103[A]/ 87[B]
Antimony	21.5	-	-	10[A]
Lead	2180	-	1150	200[A]
Manganese	2100	-	3420	1500[A]
Molybdenum	14.5	-	-	10[A]
Uranium	3620	-	-	230[A]
Benzo(g,h,i) Perylene	3.10	-	-	1[A]
Benzo (a) Pyrene	1.15	-	-	1[A]
Benzo (b) fluoranthene	3.70	-	-	1[A]
Benzo (k) fluoranthene	3.30	-	-	1[A]
Chrysene	3.20	-	-	1[A]
Dibenzo (a, h) anthracene	1.10	-	-	0.088[A]
Ideno (1,2,3) Pyrene	3.0	-	-	1[A]
Beryllium	-	66*	-	4[B]

A - Soils (mg/kg)
B - Terrestrial Organisms (ug/l)

* Addressed with the South Pines & Waste Units

TABLE 3-1

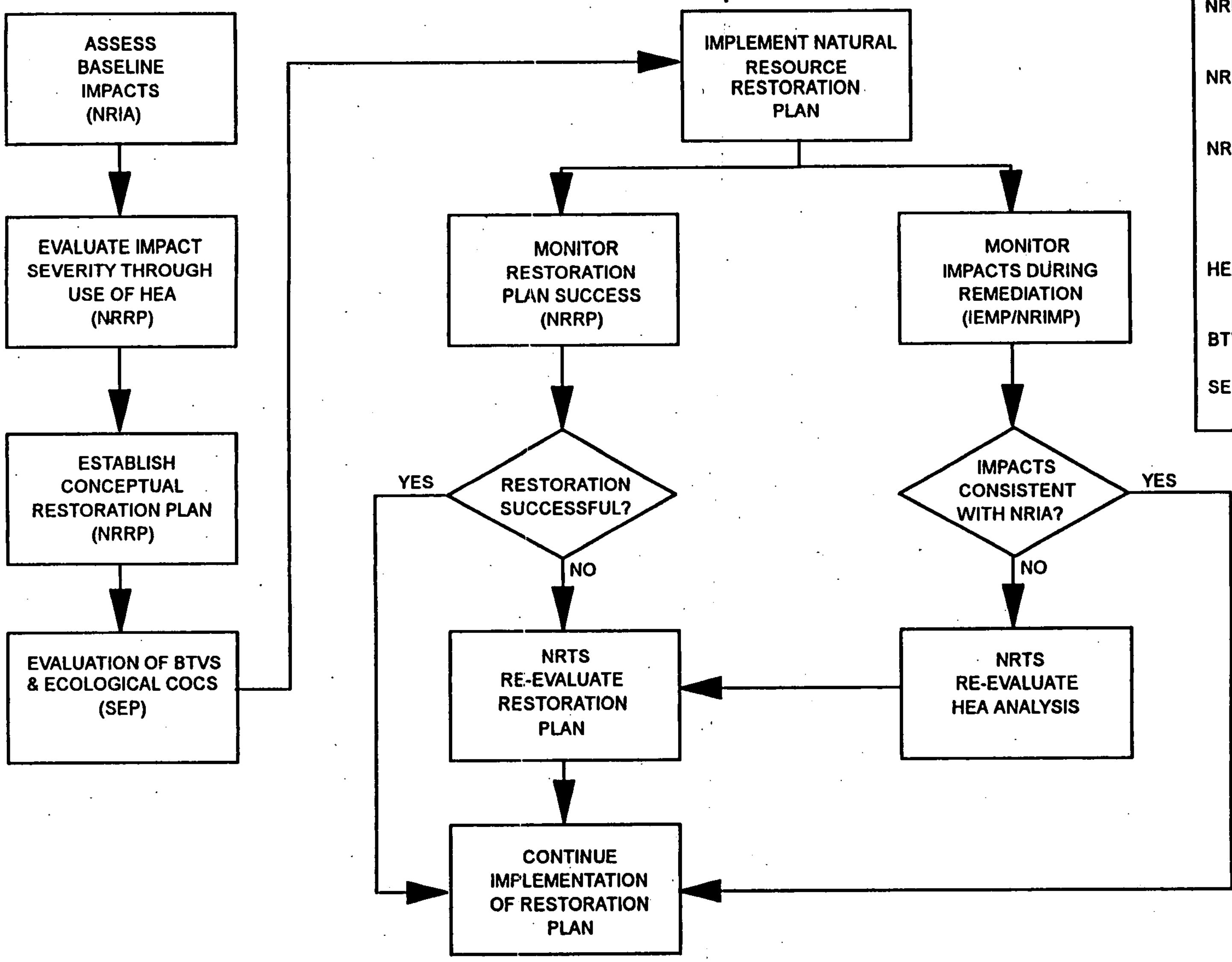
IMPACT SUMMARY

STUDY AREA

	PAST	FUTURE
GMA/GMR	172* Acres	3 Acres
Paddys Run	10 Acres	34 Acres
Southern Pines/Units	40 Acres	17 Acres
Northern Woodlot/Pines	4 Acres	40 Acres
Grasslands	93 Acres	204 Acres
Waste Pits/Process	173 Acres	-
Subtotal	492 Acres	298 Acres
TOTAL IMPACT = 790 Acres*		

* Includes aerial extent of Groundwater Plume

Figure 1-1: NATURAL RESOURCE TRUSTEE DOCUMENTATION PROCESS



NRIA: Natural Resource Impact Assessment

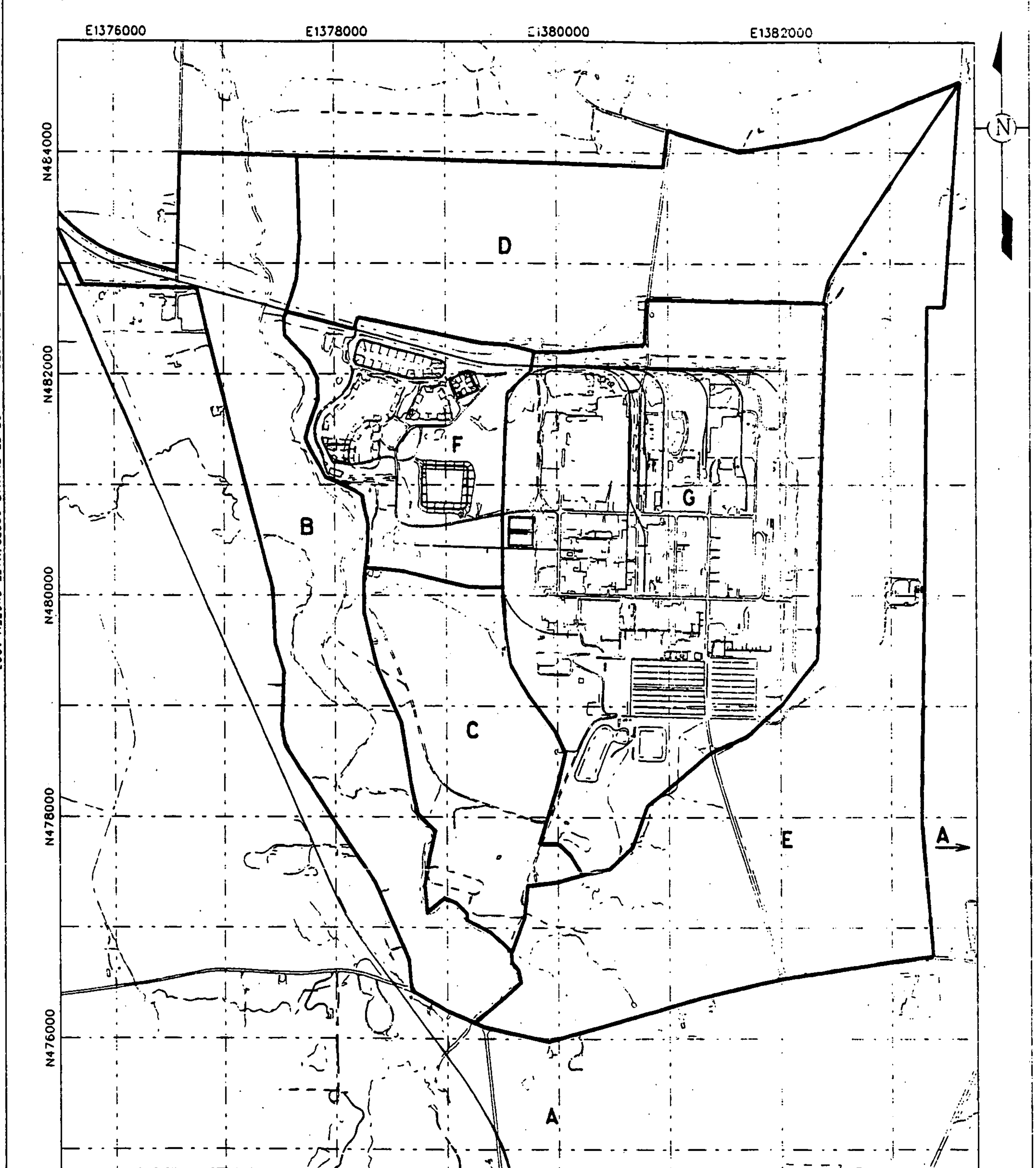
NRRP: Natural Resource Restoration Plan

NRIMP: Natural Resource Impact Monitoring Plan (Addendum to Integrated Environmental Monitoring Plan - IEMP)

HEA: Habitat Equivalency Analysis (Addendum B to NRRP)

BTV: Benchmark Toxicity Value

SEP: Sitewide Excavation Plan



LEGEND:

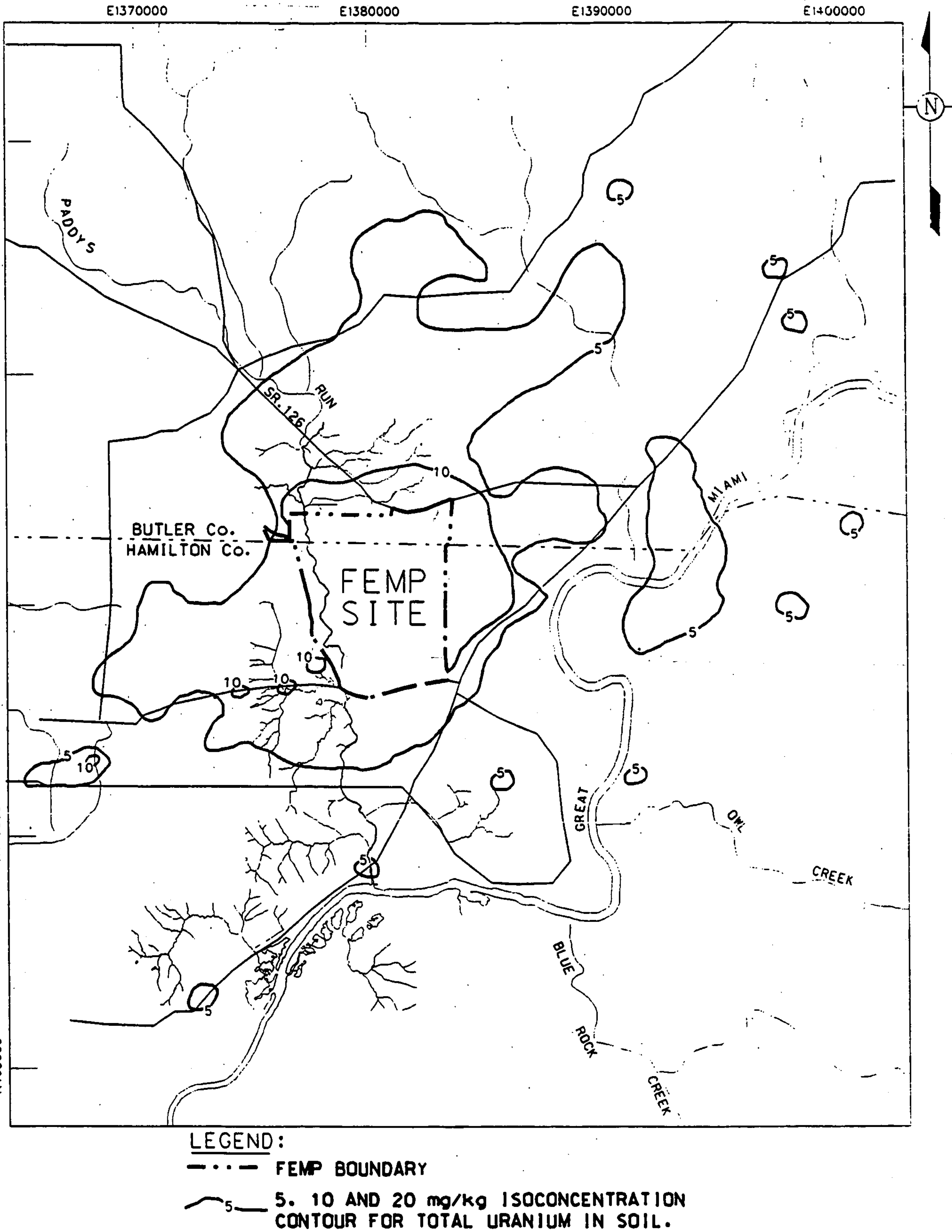
FEMP BOUNDARY
- A- G.M.R. + G.M.A.
- B- PADDYS RUN CORRIDOR
- C- SOUTHERN PINES AND WASTE UNITS
- D- NORTHERN PINES AND WOODLOT
- E- GRASSLANDS
- F- WASTE STORAGE AREA
- G- PROCESS AREA

SCALE

1200 600 0 1200 FEET

DRAFT

FIGURE 1-2. IMPACT ASSESSMENT STUDY AREAS



FILE R 3028/skg4.dgn 8x11 cru5 10-16-96 GES STATE PLANAR COORDINATE SYSTEM

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FIGURE 1-3. OFF-SITE ISOCONCENTRATION CONTOURS FOR TOTAL URANIUM IN SOIL ABOVE BACKGROUND CONCENTRATIONS

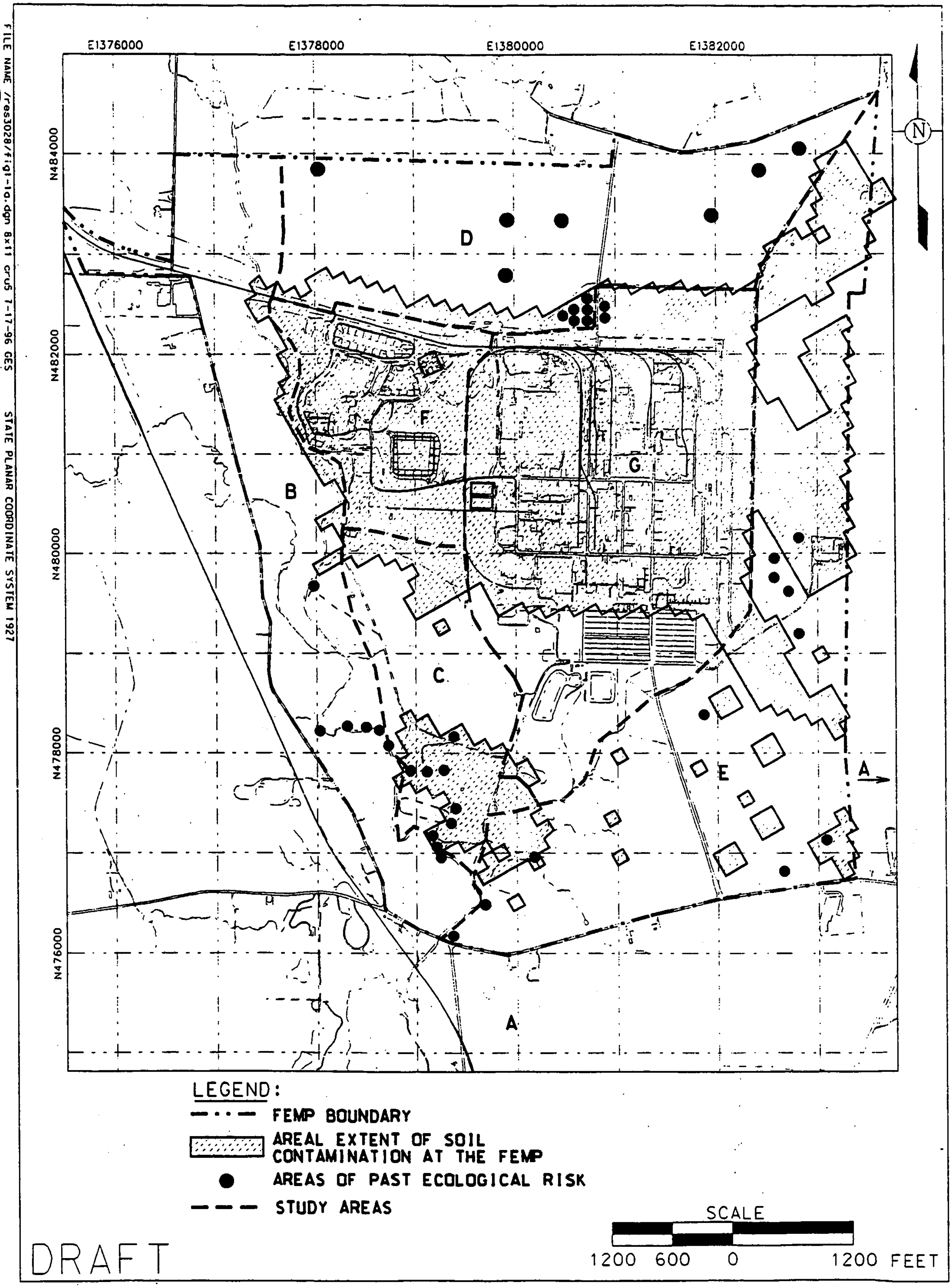

FIGURE 1-4. CONTAMINATED AREAS AT THE FEMP SITE (ABOVE FRLs AND BTVs)

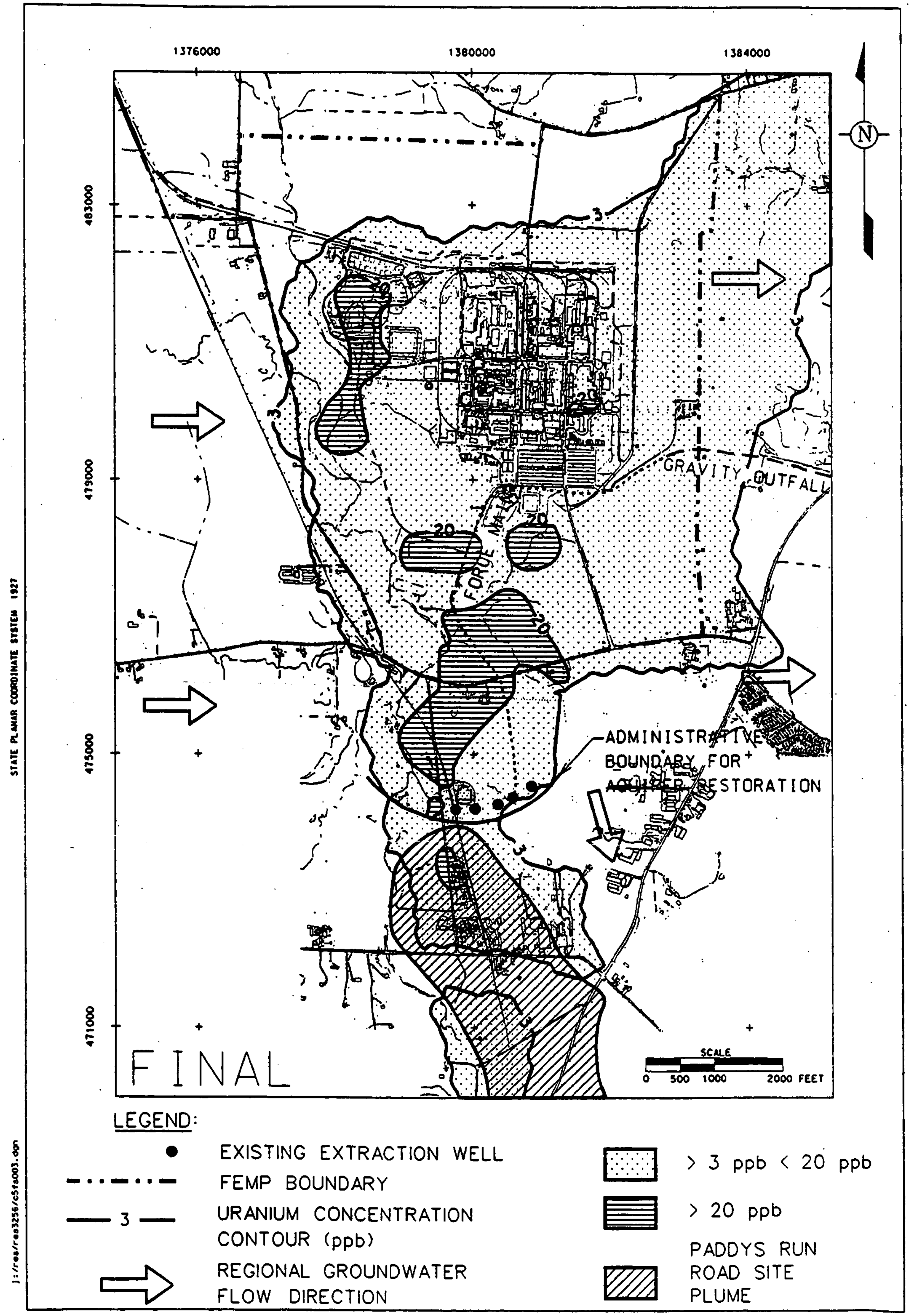

FIGURE 1-5. EXTENT OF URANIUM CONTAMINATION IN THE GREAT MIAMI AQUIFER

FILE NAME /res3028/fig2b.dgn 8x11 cru5 10-2-96 GES   STATE PLANAR COORDINATE SYSTEM 1927

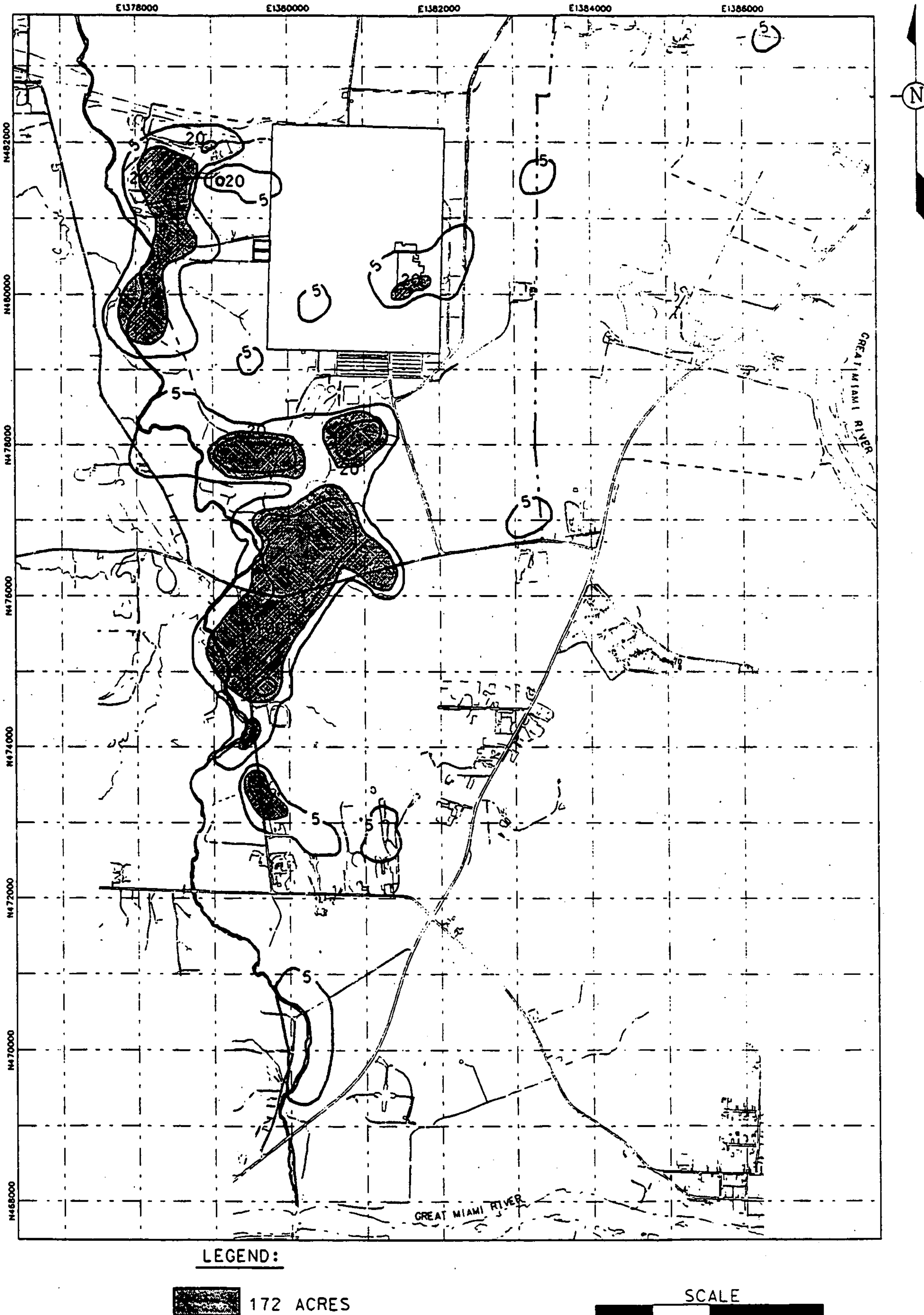

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FIGURE 2-1. EXTENT OF GREAT MIAMI AQUIFER REMEDIATION

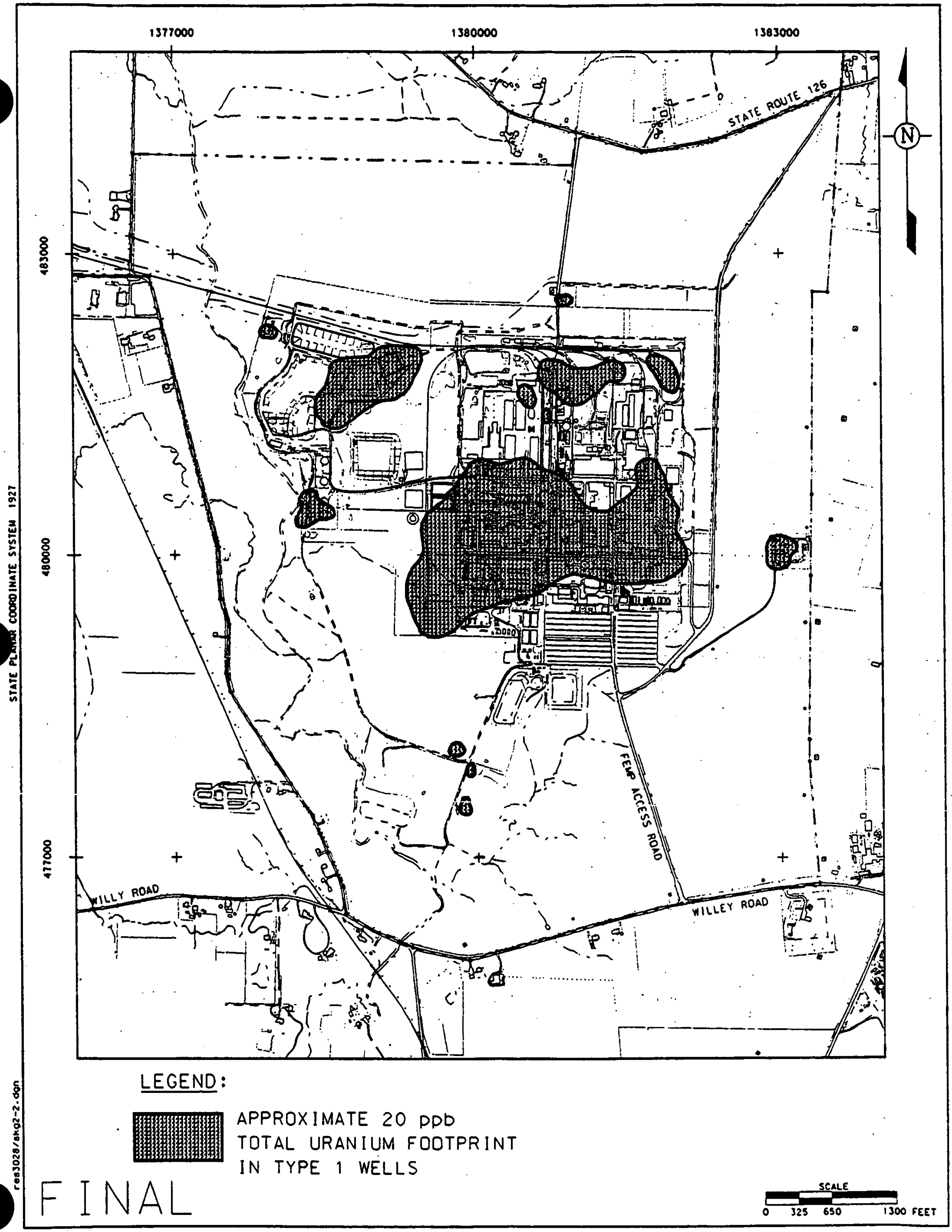

FIGURE 2-2. IMPACTED AREAS OF THE PERCHED GROUNDWATER SYSTEM

FILE NAME /es1028/fig2-3.dgn 8x11 cru5 2-18-97 GES   STATE PLANAR COORDINATE SYSTEM 1927

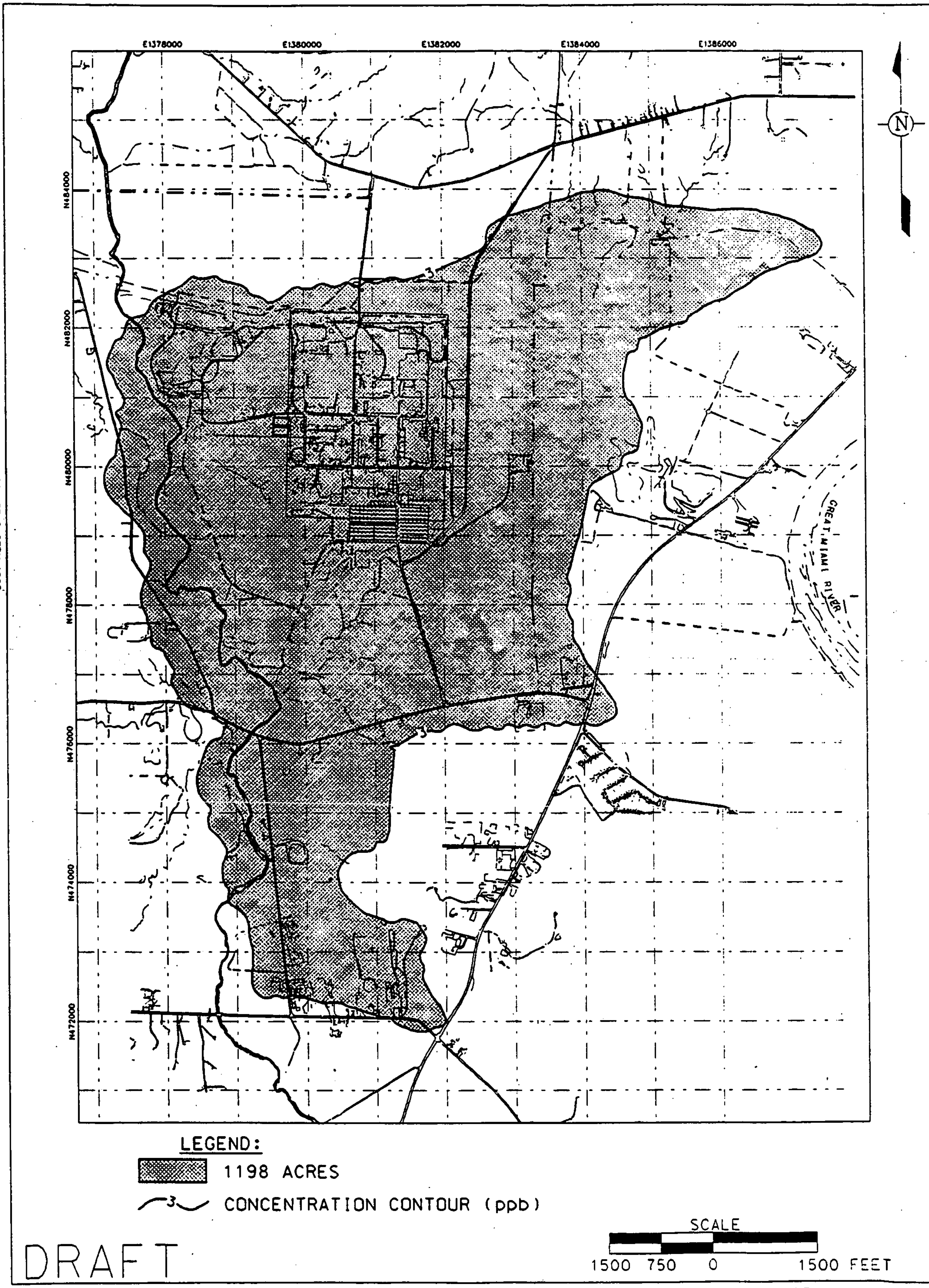

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FIGURE 2-3. RESIDUAL IMPACTS TO GREAT MIAMI AQUIFER

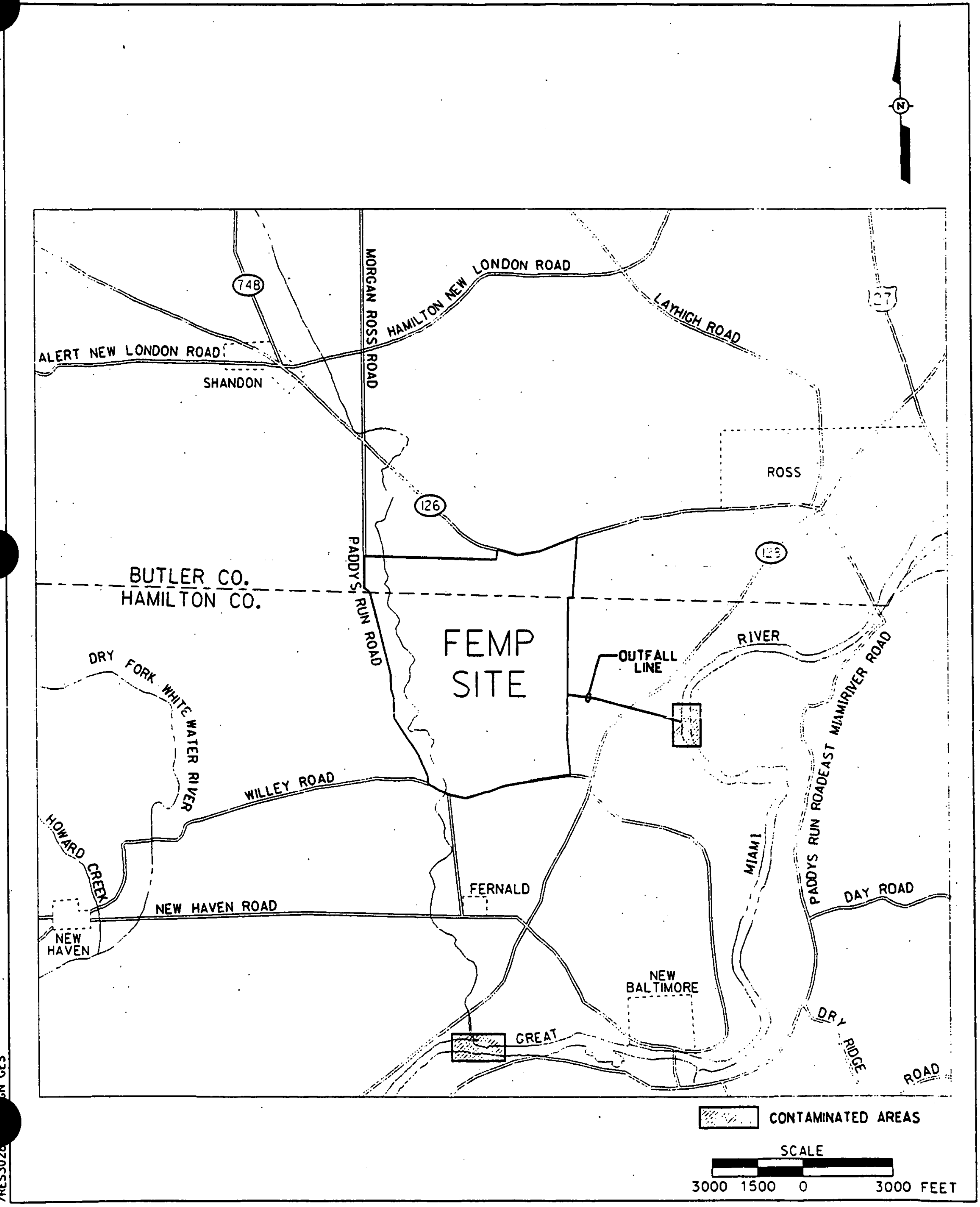

FIGURE 2-4. CONTAMINATED AREAS AT GREAT MIAMI RIVER.

FILE NAME /res3028/fig2-2.dgn 8x11 cru5 7-18-96 GES   STATE PLANAR COORDINATE SYSTEM 1927

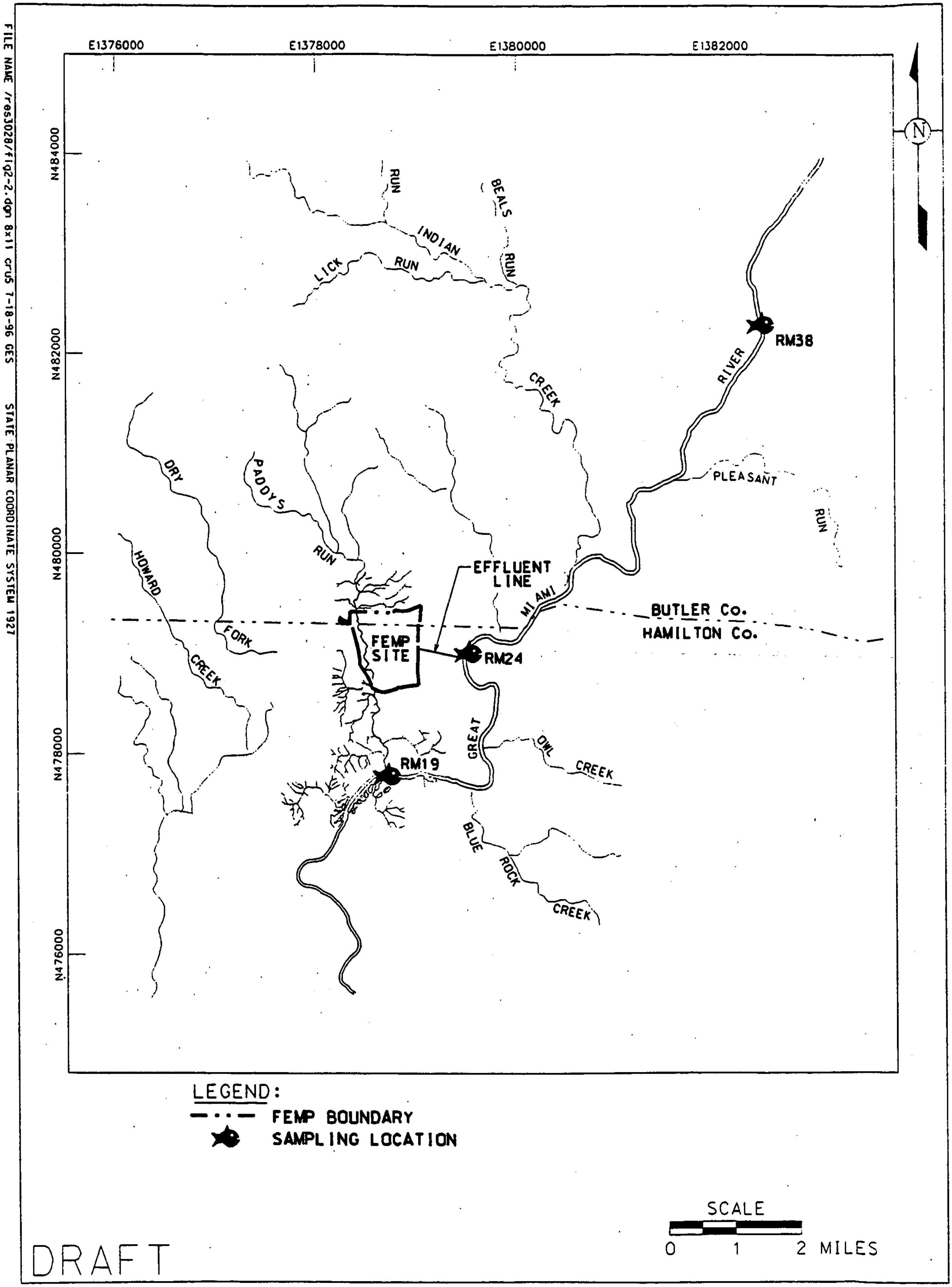

FIGURE 2-5. FISH SAMPLE LOCATIONS ON THE GREAT MIAMI RIVER

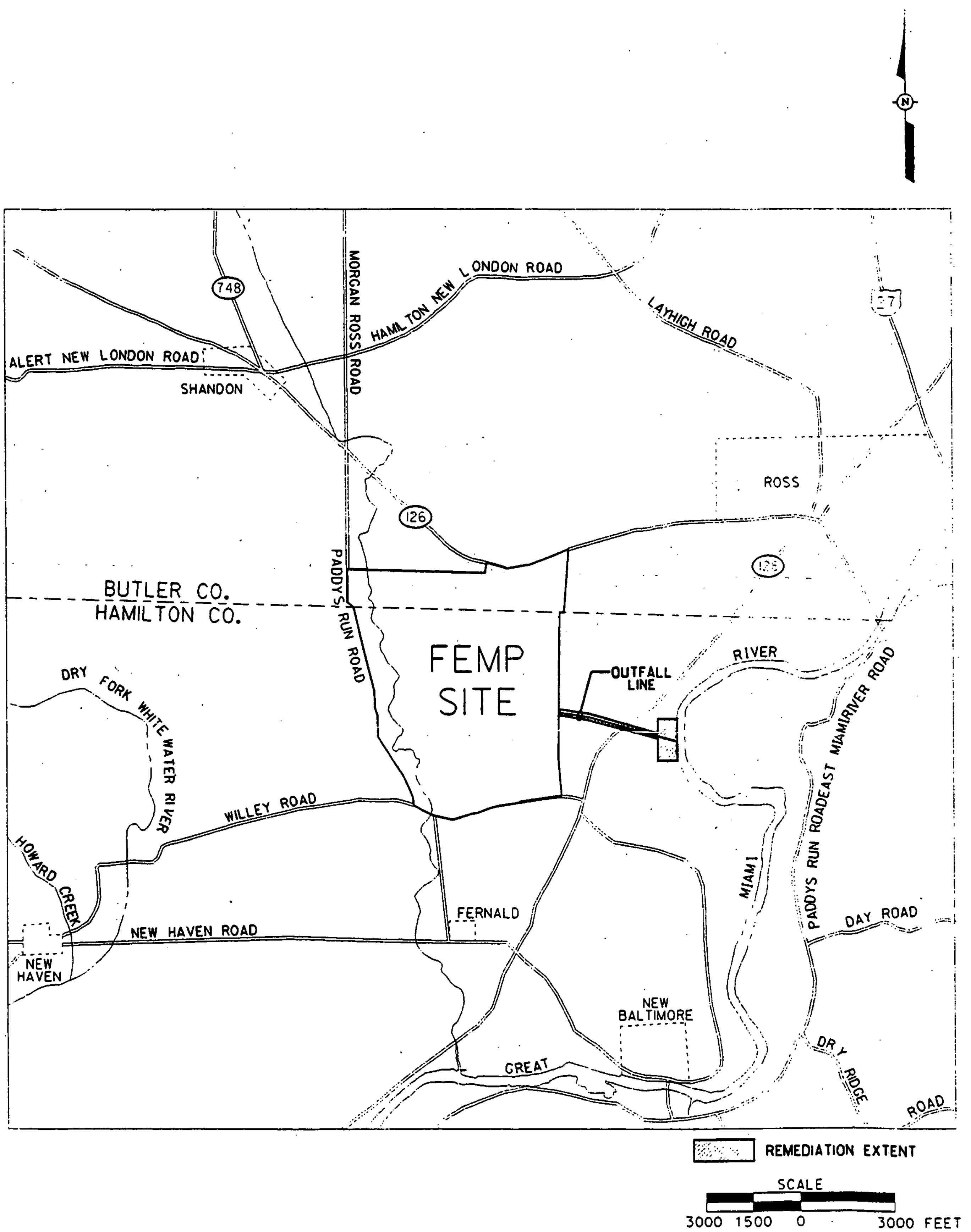

FIGURE 2-6. EXTENT OF GREAT MIAMI RIVER REMEDIATION.

FILE NAME /res3028/fig2-4.dgn 8x11 cru5 7-17-96 GES STATE PLANAR COORDINATE SYSTEM 1927

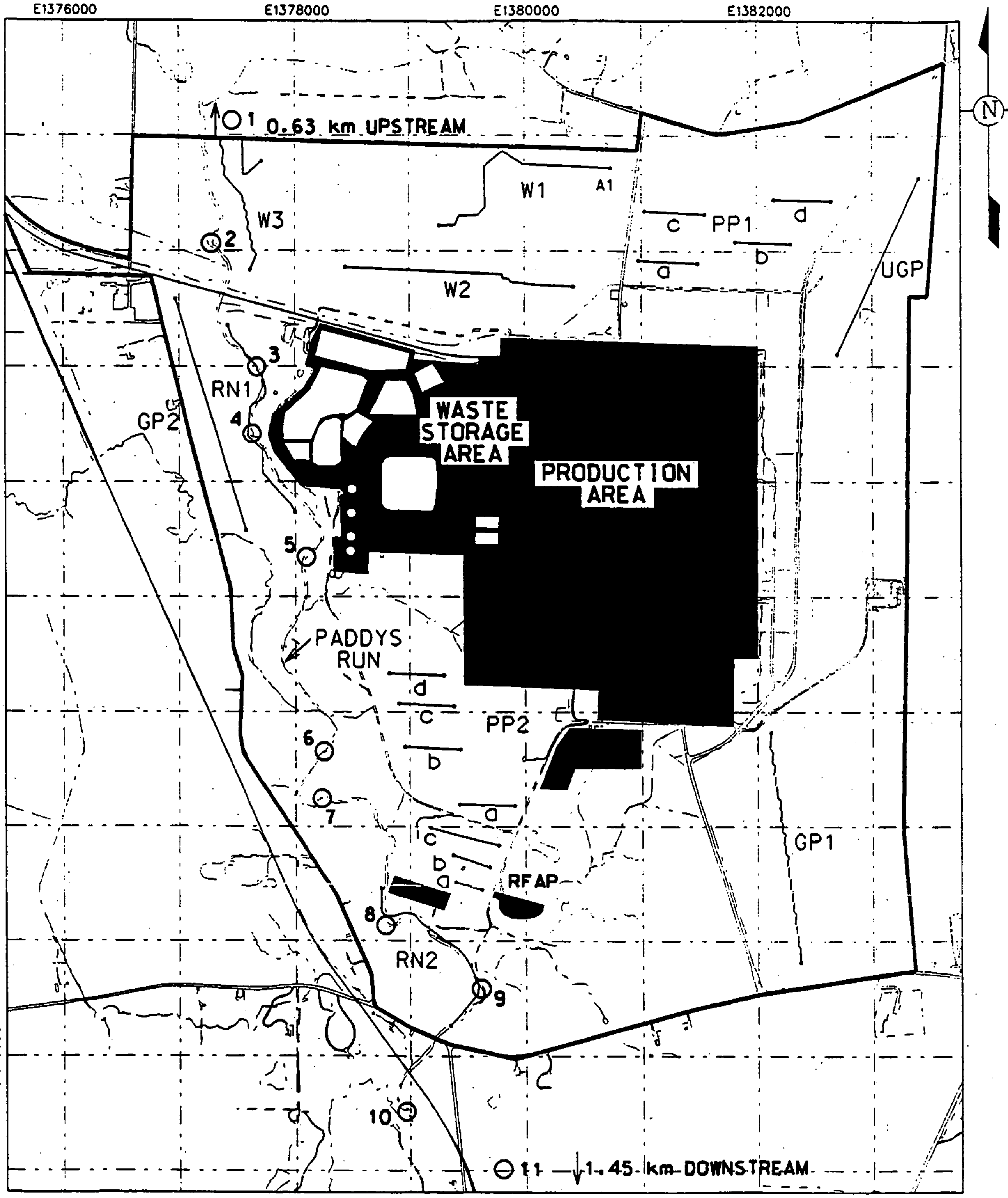

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FIGURE 2-7. MIAMI UNIVERSITY SURVEY TRANSECTS AND AQUATIC SAMPLE LOCATIONS

FILE NAME /res3028/fig1-1b.dgn 8x11 cru5 7-17-96 GES STATE PLANAR COORDINATE SYSTEM 1927

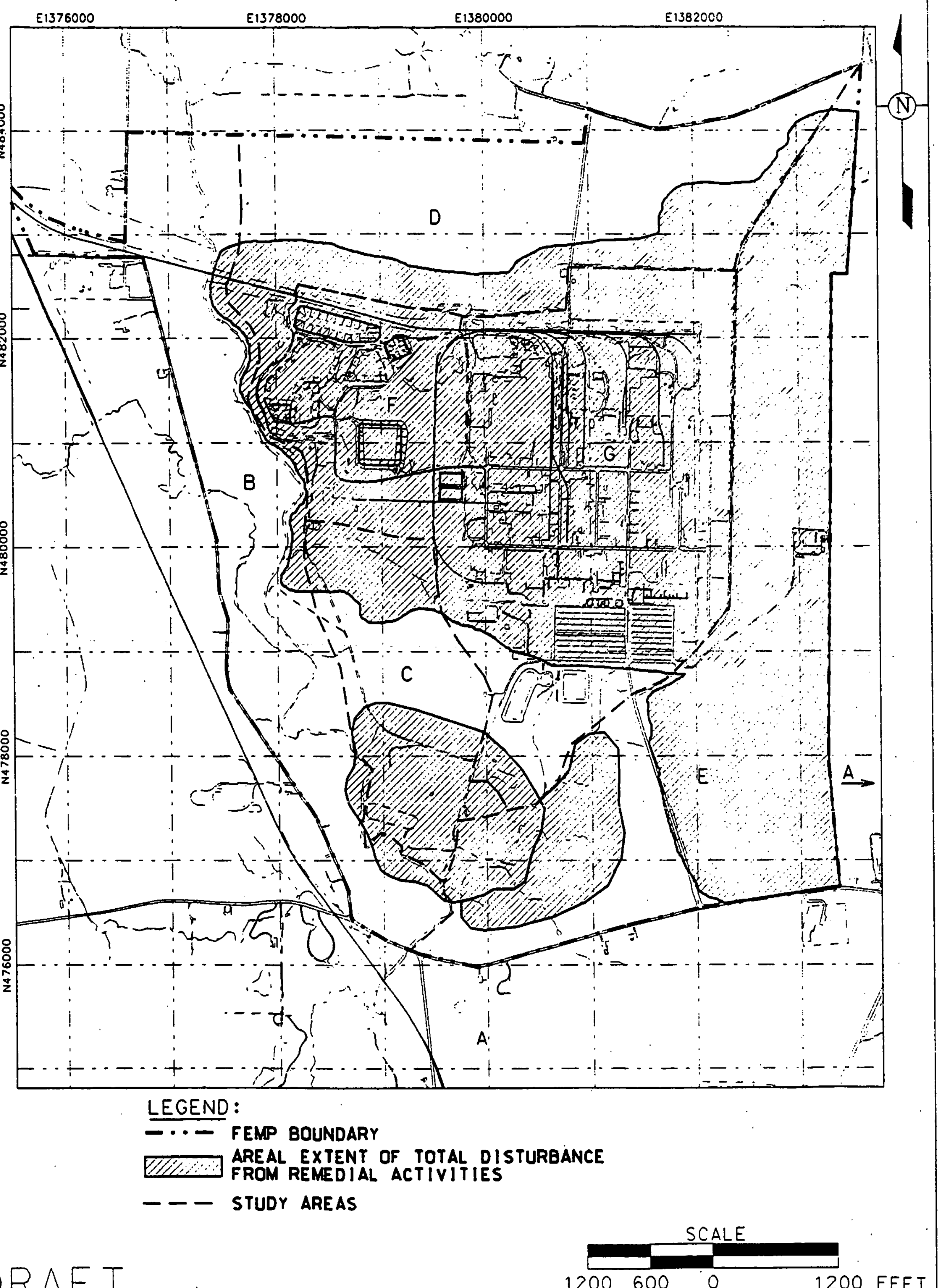

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FIGURE 2-8. AREAL EXTENT OF TOTAL DISTURBANCE FROM REMEDIAL ACTIVITIES AT THE FEMP

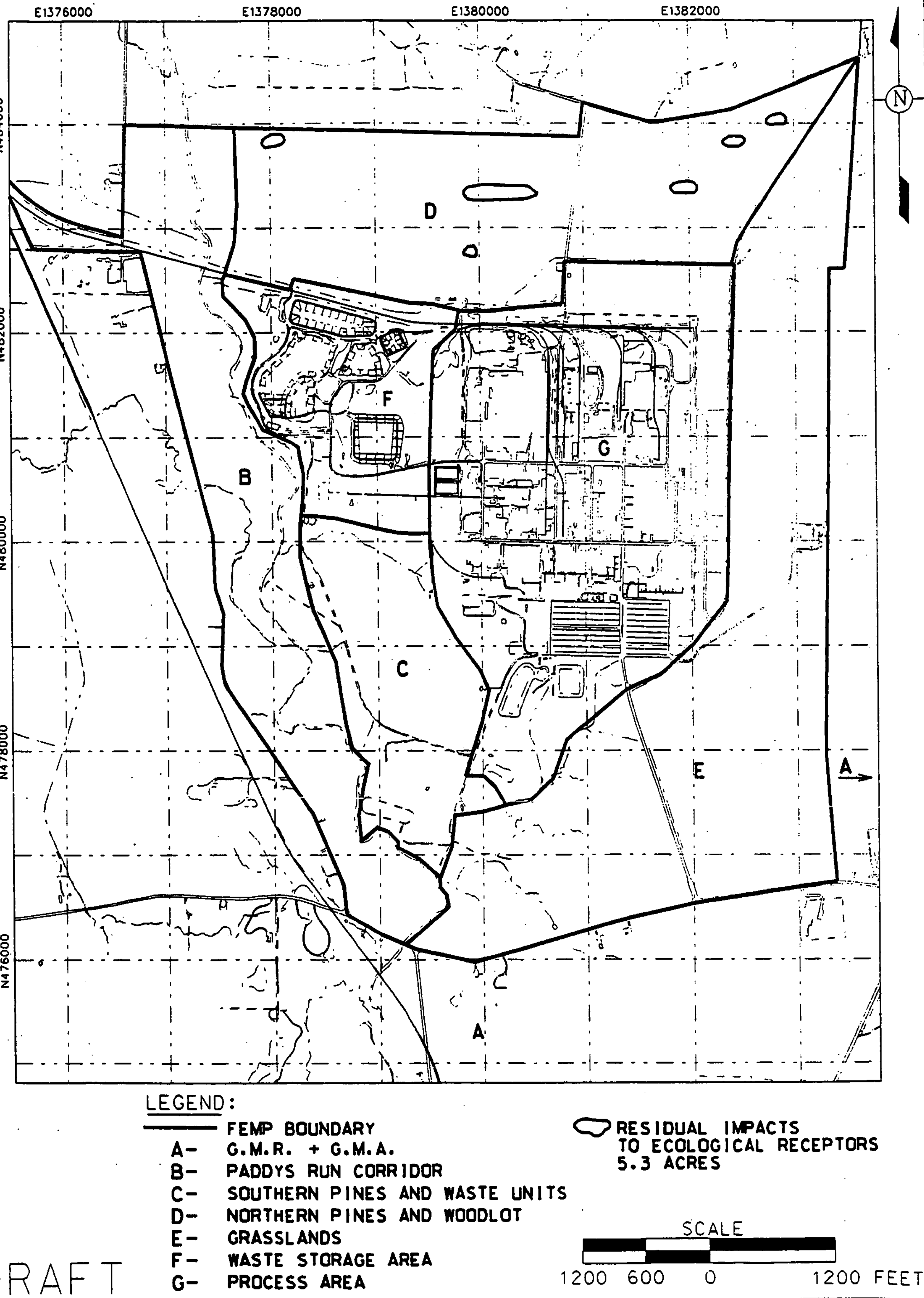

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FIGURE 2-9. RESIDUAL IMPACTS TO ECOLOGICAL RECEPTORS

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NATURAL RESOURCE RESTORATION PLAN

~~An Environmental Reference Document to the Sitewide Excavation Plan~~

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

JULY 1997

U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

212E-PL-0003
REV. C
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LIST OF ACRONYMS

ASCOC	area-specific constituent of concern
BOD	biochemical oxygen demand
BTV	benchmark toxicity value
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy, Fernald Field Office
EPA	United States Environmental Protection Agency
ERD	Environmental Reference Document
FCTF	Fernald Citizens Task Force
FEMP	Fernald Environmental Management Project
FRL	final remediation level
FWS	Free Water Surface
HEA	Habitat Equivalency Analysis
NRDA	Natural Resource Damage Assessment
NRIA	Natural Resource Impact Assessment
NRRP	Natural Resource Restoration Plan
OEPA	Ohio Environmental Protection Agency
OSDF	On-site Disposal Facility
RI/FS	Remedial Investigation/Feasibility Study
SEE	Sitewide Extent of Excavation
SEP	Sitewide Excavation Plan
TSS	total suspended solids

1.0 INTRODUCTION

The Natural Resource Restoration Plan (NRRP) ~~is designed to be a comprehensive plan that will implement the overall objectives for land use and identify the necessary institutional controls at the Fernald Site by restoring and committing portions of the site to natural resource preservation. The NRRP provides a programmatic approach for expedited natural resource restoration at the site. Early restoration will include the concept of initiating restoration activities upon completion of area specific remedial activities, and as an essential design component for grading activities. Therefore, restoration activities under the scope of this plan will be coordinated with the FEMP's remediation activities as a support plan to the Sitewide Excavation Plan (SEP). The projects outlined in the NRRP are designed to address a number of regulatory commitments related to natural resource impacts.~~ outlines the overall objectives for restoration and final land use at the Fernald Environmental Management Project (FEMP). It also identifies the institutional controls necessary to restore and commit portions of the FEMP to an Undeveloped Park with an emphasis on wildlife habitat. The NRRP presents the strategy for site restoration, and provides a programmatic approach for expediting natural resource restoration to the extent practicable. The final land use at the Fernald Site will be determined with the full involvement of the public and other stakeholders. It is possible that some areas of the site could be identified for alternative uses based on stakeholder input. The NRRP is based on a series of near-term and long-term restoration projects that are designed to address compensatory requirements on the part of DOE for natural resource impacts and a number of regulatory commitments related to natural resource impacts.

~~This plan serves as a support plan to the Sitewide Excavation Plan and is, by design, an integral aspect of the sitewide remediation process. For these reasons, this support plan is a "living document" that will be revised and updated to reflect current remediation conditions throughout remediation. The final iteration of this plan will also serve as a final land use plan and as the decision document for sitewide institutional controls.~~

The NRRP is an integral aspect of the sitewide remediation process and has been developed in coordination with the excavation plans outlined in the Sitewide Excavation Plan (SEP). For these reasons, the NRRP is a "living document" that will be revised and updated to reflect current conditions throughout remediation. The final iteration of this plan will also serve as a Final Land Use Plan and as Sitewide Institutional Controls Plan.

1.1 ~~Natural Resource Restoration Strategy~~ Goals of the Natural Resource Restoration Plan

The ultimate goal of the NRRP is to resolve DOE liability for past and future natural resource ~~injuries~~ impacts at the FEMP while meeting regulatory commitments and addressing stakeholder concerns. ~~Restoration goals were also established to guide the development and implementation of the NRRP.~~ It is essential that the Natural Resource Trustees concur with the approaches and projects outlined in the plan before detailed design can begin on individual projects. In addition, other stakeholders will be provided the opportunity to review the plan to ensure a general consensus is reached on the conceptual final land use for the site. The specific goals that guided the development of the NRRP are as follows:

- Establish a restoration plan satisfactory to all Natural Resource Trustees and upon implementation will resolve DOE liability for impacts to natural resources associated with the ~~Fernald Site~~ FEMP
- Propose a future land use for the ~~Fernald Site~~ FEMP site that considers the interests of all stakeholders and will benefit the surrounding area
- Propose a future land use that is consistent with the established risk levels in the various ~~Operable Unit Records of Decision; and~~ operable unit records of decision (RODs)
- Establish a restoration plan that can be fully integrated with the ongoing remedial design and remedial action processes at the FEMP.

1.2 Natural Resource Restoration Strategy

The natural resource restoration strategy for the FEMP is to implement a series of specific projects both during and after the completion of site remediation. The restoration projects will be fully integrated with ~~Remedial Design and Remedial Action processes for Operable Unit 5 (i.e., soil excavation and remediation). The strategy for natural resource restoration at the site is to implement near-term projects in parallel with site remediation activities to enable DOE demonstration of progress towards full restoration of the site. Full restoration would be accomplished through the completion of near-term projects during remediation, as well as additional long-term projects after site remediation.~~

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the remedial design and remedial action processes for Operable Unit 5 (i.e., soil excavation and remediation) where appropriate. The strategy includes:

- Initiating restoration activities at the completion of area-specific remedial activities wherever possible
- Coordinating restoration activities under the scope of this plan with FEMP remediation activities
- Incorporating restoration goals into the design of grading activities.

The initial strategy for natural resource restoration at the site is to begin near-term restoration projects in parallel with site remediation activities, and accomplish full restoration through additional long-term projects at the completion of site remediation. Projected near- and long-term restoration projects are discussed in Section 3.0.

The NRRP strategy will also incorporate the restoration goals of the Fernald Natural Resource Trustees and the input of other Stakeholders in establishing an acceptable final land use for the FEMP. Institutional controls for the FEMP property will be developed to support final land use agreements.

1.3 Summary of Natural Resource Impact Assessment

The Natural Resource Impact Assessment (NRIA) identified the impacts (i.e., injuries) at the site resulting from past contamination, ~~as well as~~ and those impacts expected to occur as part of future remedial actions. The NRIA identified impacts to the extent possible on an acreage basis sorted by habitat type. Groundwater impacts were identified on both an acre and volumetric basis as groundwater does not constitute a "habitat." In general, impacts were quantified using existing ~~RI/FS~~ remedial investigation/ feasibility study (RI/FS) information. Past impacts were measured using the soil excavation footprint, which ~~showed~~ included soils that were considered a risk to human ~~or ecological receptors (i.e., FRLs or BTVs)~~ receptors [i.e., soil concentrations exceeding Final Remediation Levels (FRLs)]. Future impact acreage ~~as~~ was identified in cases where physical disturbances have resulted from or will result in the destruction or reduction in the quality of a particular habitat. Past and future combined impacts at the FEMP were estimated at approximately

~~over 598 acres either through past contamination or future remedial activities~~ 618 acres. In addition, 172 acres of groundwater impact was estimated to have occurred from past production operations.

The purpose of the NRIA is to establish a "baseline" level of impact from which appropriate restoration activities can be developed. The NRIA was designed to function in a manner analogous to an Injury Determination in the formal Natural Resource Damage Assessment (NRDA) process (43 CFR 11). ~~While it was the intent~~ Since the intent of the Fernald Natural Resource Trustees is to pursue a more streamlined evaluation and assessment process and not to conduct a formal NRDA, the NRIA and NRRP were designed to meet the substantive aspects of ~~that process as offered under the regulations~~ the formal NRDA process to the extent practicable.

The level of impacts identified in the NRIA will be used to assess a required level of natural resource restoration utilizing the Habitat Equivalency Analysis (HEA) process ~~outlined in Section 1.3 (also see Appendix A).~~ described in Section 1.4 and Addendum B. The results of the HEA ~~were used~~ will be used to establish the restoration activities outlined in Section 3.0 of this plan. The NRIA will be approved as a final document with no further revisions. The NRRP will be a "living" document and may be revised throughout this process as defined in Section 2.2. The relationship of these documents is outlined in Figure 1-1.

It should be noted that the NRRP considers restoration projects with respect to future land use and associated habitats only. Although groundwater is not considered a habitat, compensatory restoration required as a result of past or future impacts to groundwater resources will also be met through future land use planning. In other words, compensation for groundwater impacts is being implemented through habitat restoration.

1.4 Summary of Habitat Equivalency Analysis

The ~~Habitat Equivalency Analysis~~ HEA process was utilized to ensure that the level of natural resource restoration outlined in this NRRP is commensurate with the level of impact identified in the NRIA. ~~Since all impacts except groundwater were identified on a "habitat" basis (as opposed to a resource-by-resource designation), HEA was effective in determining the level of required restoration based on the impacts identified in the NRIA. The use of HEA allows for consideration to be given to the severity of the impact (as determined by the NRTs collectively and the time frame in which the~~

~~impact occurred). The HEA process was used as the substantive equivalent of the Damage Assessment phase of the formal NRDA process.~~ HEA methodology provides a means of compensating for natural resource injury through the calculation of habitat restoration acreage. By linking estimates of service loss over time to service gains through restoration projects, the potentially contentious dollar damage estimates may be avoided.

1.5 Future Land Use

The projects outlined in the following sections will ~~lead to a final land use with an emphasis on natural resource protection and preservation with consideration given to other possible uses of portions of the Fernald Site.~~ contribute to an Undeveloped Park with an emphasis on wildlife management as the final land use. Consideration will also be given to other possible uses of portions of the FEMP depending on stakeholder input. Figure 1-2 presents the most current version of the conceptual final land use. The primary focus of the restoration activities will be to establish a system of wetland and open water habitats with supporting woodlands and grasslands to support a diverse natural system. In addition, the Paddys Run corridor will be preserved and enhanced to further ~~diversify the restored area~~ contribute to diversity. Other areas such as the buffer zone for the OSDF will also support a natural habitat while providing an aesthetic buffer for the local community.

~~Other key aspects of the plan will be to:~~

- ~~Provide a passive wetland system to treat storm water run off from the OSDF prior to its discharge off property~~
- ~~Provide an area for the reburial of Native American human remains as part of the final land use of the site~~
- ~~Provide access to the site through a series of walking/bike trails with interpretive signs. There will be portions of the site that will not be "accounted for" as an integral part of the NRRP and could be available for uses other than natural resource restoration. Figure 1-2 provides a conceptual representation of the future land use at the FEMP resulting from the implementation of the NRRP, based on the anticipated final future grade at the site.~~

This approach will provide the basis for future land use and allow DOE-~~FN~~FEMP to meet its ~~NRT~~ Natural Resource Trustee and regulatory responsibilities, while at the same time satisfying the future use recommendations of the ~~FCTF~~ Fernald Citizens Task Force (FCTF) and other stakeholders.

2.0 RESTORATION PLANNING

The restoration projects proposed in this NRRP have been developed by considering the extent of excavation and grading and the sequence of remediation activities so that restoration and establishment of the future land use can be expedited. ~~to the extent possible.~~ In addition, consideration was given to uncertainties and a variety of other regulatory and technical considerations. This section will provide the basis for the proposed restoration projects and conceptual final land use outlined in this plan.

2.1 Integration with ~~other Support Plans Environmental Reference Documents~~Sitewide Excavation Plan

The ~~timing for the~~ sequencing of the implementation of the restoration projects proposed in this plan will be driven by the timing and sequencing of soil excavation. In addition, the final appearance of the site will be a function of the extent of excavation and final grading required during soil remediation. This section ~~shows~~ addresses how implementation of the projects outlined in the NRRP will be integrated with the guidelines established in the SEP and its appendices.~~the other SEP support plans.~~ Restoration activities will also rely on various applications of sitewide monitoring identified in the IEMP.

2.1.1 Sitewide Excavation Plan

~~Certain guidelines established in the SEP define the basis for site restoration. Those guidelines and the corresponding sections of the SEP where they can be found are as follows:~~The NRRP is fully integrated into the SEP. Many issues identified in the SEP apply directly to the NRRP, such as:

- Restoration strategy ~~(2.0)~~
- Regulatory drivers ~~(2.0)~~
- Certification and BTVs ~~(3.0)~~
- Restoration Grading Guidelines ~~(4.6)~~
- Environmental Monitoring ~~(5.0)~~
- Quality Assurance/Quality Control ~~(8.0)~~.

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2.1.2 Post-Excavation Strategy

A key component of the proposed future land use ~~are~~ is a series of interconnected open water and wetland habitats. A fundamental assumption during the development of this plan was that excavations required for soil remediation would be utilized for natural resource restoration to the maximum extent possible. ~~Therefore, the specific locations and sizes of the open water/wetland areas were driven by the requirements for excavation outlined in the Sitewide Extent of Excavation Plan. In addition, the general pattern of site drainage for proposed final land use was established through the utilization of trenches that will be formed through the excavation of site utilities. The SEE is based on FRLs, not BTVs.~~ There will be a variety of excavations in and adjacent to the Former Production Area that could potentially accommodate the wetland and open water habitat (Figure 2-1). The specific locations and sizes of the open water/wetland areas were based on the requirements for excavation. In addition, the general pattern of site drainage for proposed final land use was established through the utilization of trenches that will be formed through the excavation of site utilities.

2.1.3 ~~Sitewide Phasing Plan~~ Sitewide Sequencing Plan

The Sitewide ~~Phasing~~ Sequencing Plan dictates the sequence and timing of soil remediation activities which will dictate the schedule for implementation and completion of long-term restoration projects. For example, revegetation of the production area would be delayed until the certification process is complete for the area-specific constituents of concern (ASCOCs) of a remediation area. The near-term restoration projects have been designed to be implemented in tandem with soil remediation. However, the certification of certain areas to below FRL concentrations will ~~have to~~ occur prior to the implementation of on-site, near-term restoration projects.

2.1.4 Sitewide Grading Plan

The Sitewide Grading Plan will provide the transition from the excavated areas resulting from soil remediation to the appropriate grades to support natural resource restoration. The Grading Plan will ensure that appropriate drainage is established, slopes are stabilized, and appropriate surface water diversion and retention are established to support open water/wetland habitats. The grading plan will also ensure that the floodplain of Paddys Run is not restricted as a result of soil remediation and that areas of the site for alternative use will be graded appropriately.

2.2 Uncertainties and Considerations for Accelerated Restoration

There are several aspects of the NRRP and the acceleration of the natural resource restoration process that involve uncertainties that must be addressed through careful consideration in the project specific design processes. ~~Two of the considerations are the potential for cross contamination during excavation and the establishment of a process to deal with ecological risk considerations which are discussed in detail below.~~ The primary uncertainty is that impacts during remediation may be more extensive than anticipated in the NRIA. Section 2.2.1 provides the approach for dealing with these cases.

2.2.1 Process For Changing Impact Severity

The scope and extent of the projects outlined in this plan are designed to compensate for the amount of impact outlined in the NRIA and further quantified into required restoration acreage through the HEA process in Addendum B of this Plan. It is anticipated that situations could arise in the future where the magnitude of impacts that actually occur in the field will differ from those identified in the NRIA. Verification of the amount of impacts occurring in the field will occur through implementation of the Nature Resource Impact Monitoring Plan (NRIMP). The NRIA, once approved, will not be revised to reflect these changes. However, differences in magnitude of impacts will be reflected through updates in this NRRP and the HEA in Addendum B. Changes in the magnitude of natural resource impacts are anticipated to occur primarily from the following activities:

- NRIMP monitoring identifies and confirms the impact that the NRIA identified due to the extent of disturbance from remediation; and
- Sampling during certification identifies residual BTVs which result in impact or a needed change in the extent of excavation or habitat as defined in this NRRP.

The design for an individual restoration area will be incorporated in the IRDP for a specific excavation area. The restoration design will be subsequently approved by the Agencies and Natural Resource Trustees. Upon approval by the Agencies and NRTs, the design drawings will be ready for issuance to potential vendors in a Request for Proposal for the implementation of a specific restoration project. At this point, the NRRP will be updated to reflect the approved drawing as the final restoration plan for that particular area. In other words, the NRRP will be revised at the completion of each IRDP.

Therefore, the revision of the NRRP to reflect the final project drawing will present the best opportunity to update the HEA and make any necessary adjustments in the Restoration Plan to compensate for additional unexpected impacts or impacts that prove to be less than anticipated. The HEA tables will only be recalculated for those impacted areas greater than 2 acres. The text of the HEA evaluation will also be revised to note the change and the specific impact that has caused the change to those areas greater than 2 acres. Past implementation of HEA indicates that minor changes to service levels would not affect restoration acreage appreciably. In other words, impacts less than 2 acres would not be expected to increase habitat acreage to the extent that would require changes to restoration design.

In addition, the NRRP will change due to the expansion or reduction of a particular project to compensate for the greater/lesser impact. The change will also be noted in the text of the NRRP to make it clear what project has been expanded and for what reason (i.e., impact). Under this approach the final version of the NRRP and HEA will contain a compilation of all revisions that have occurred throughout the remediation process and the NRTs will be able to account for all unanticipated impacts and identify the specific project that has been revised to compensate for that impact.

2.2.2 Potential for Cross-Contamination During Phasing of Excavation

The potential for cross-contamination is a concern that must be addressed during the excavation and grading processes. The overall excavation and grading processes will require that particular areas of the site be excavated and graded before or in parallel with other areas. Appropriate administrative and engineering controls must be in place so that cross-contamination is minimized. The specific projects outlined in this plan will not be implemented until the certification process is complete for each respective project area and appropriate controls are established to ensure the risk of cross-contamination has been minimized.

2.2.3 Ecological Risk Factors

A process must be established to ensure that the projects proposed are not implemented in areas that contain contaminants posing a risk to ecological receptors. The process will be designed to effectively address the impact of potential contaminants to ecological receptors.

Appendix C of the Sitewide Excavation Plan contains the sitewide review of ecological contaminants of concern. The results of this review indicate that antimony, cadmium, and silver may be a concern in a few limited areas of the site. However, remedial activities are anticipated to address any ecological concerns, which will be verified during the certification process. Any remaining ecological concerns will be addressed through the NRRP.

~~The general approach for addressing ecological risk concerns will be based on BTVs, which will be re-evaluated to define the contaminant concentrations that actually pose a risk to ecological receptors for a given habitat. The evaluation of BTVs in each remediation area will consist of include the following:~~

- ~~Selecting the habitats desired for the site~~
- ~~Identifying the BTVs at the excavation depth of the remediation area~~
- ~~Evaluating mitigation measures that may be taken to address BTVs of concern (i.e. further excavation, lining the excavation with below BTV & FRL borrow equipment).~~

2.3 Restoration Decisions

This section outlines other considerations that were factored into the establishment of the specific restoration projects and the final land use outlined in this plan in addition to the issues outlined above.

2.3.1 Soil Balance and Pre-FEMP Topography (i.e., Cut and Fill Maps)

Topographic maps for the site prior to the construction of the Fernald Plant have been utilized to construct a profile of the topography and drainage in the years prior to 1952. In designing the natural resource restoration projects, every effort will be made to re-establish original drainage patterns by ~~mimicking~~ restoring pre-site topography and elevations to the extent possible (see the Sitewide Extent of Excavation). The premise for this approach is that the site, over the long term, will tend to erode back to conditions that existed prior to construction of the FEMP. Therefore, reestablishing the "natural" drainage patterns should add to the success of restoration projects (i.e., wetlands and open water) in the long term.

2.3.2 Sequence of Natural Resource Restoration Projects

The general approach for sequencing the projects outlined in the NRRP is to implement the near-term restoration projects starting in 1998, with approximately one project a year for the next ~~7-8~~ seven to eight years. The long-term restoration projects will be implemented as soil remediation is completed and ~~the grading of areas to support restoration can be accomplished~~ areas can be graded to support restoration. Specific schedules are provided on a project basis (to the extent they can be defined) in Section 3.0.

2.3.3 Available Watershed

~~The total available watershed to the FEMP site will be considered in the viability of the proposed habitats. The extent to which open water/wetland habitats can be supported will be a function of the amount of water available.~~ The Water Availability Study (Addendum C) provides quantitative modeling results regarding the surface water routing involving four open water areas under post-remediation conditions at the FEMP. The modeling results indicate that four on-property open water areas can be established in the former production area and its vicinity as a result of soil excavation activities.

Average water depths were determined by dividing the pond storage capacity by the surface water area. The average water depths in the four open water areas are 8.2, 10.5, 4.5, and 14.8 feet respectively. The acreage associated with the four open water areas under normal conditions at the minimum stage are 10, 12.5, 6.1, and 3.3 acres, respectively. An evaluation of the available ~~watershed in the post remediation topography will conducted in early CY 1997.~~ water within the postremediation topography is provided in Addendum C and does appear to be able to support the establishment of open water/wetland systems.

3.0 NATURAL RESOURCE RESTORATION PROJECTS

~~Near-term restoration projects are projects that may be performed in the next two to eight years either in on-property areas that will not be disturbed by remediation or in off-property areas. There are several reasons for the implementation of near-term restoration projects. First, some restoration is compliance-driven and is required to meet regulatory commitments. An example is wetland mitigation. DOE committed to U.S. EPA and OEPA to restore or create 15 acres of on-property wetlands before remedial activities are completed. Therefore, a near-term wetlands mitigation project is required. Second, near-term restoration projects will also contribute to the overall objectives of site restoration by providing a mosaic of habitats at different stages of maturity. Third, by staggering area-specific restoration projects over a number of years, it will distribute the funding to meet the overall sitewide restoration goals. This approach also allows for certain areas to benefit much sooner than they would otherwise if only post-remedial restoration was undertaken.~~

This section describes the near-term and long-term restoration projects proposed for the FEMP. These descriptions provide a conceptual sketch of the components required for each project. Once the detailed design process is undertaken, specific components of the various projects may be revised.

3.1 Near-Term Restoration Projects

~~The restoration projects considered for the FEMP site are described below. Some of the restoration projects are defined in areas that correlate with the site's remediation area boundaries, as shown on Figure 3-1.~~ Near-term restoration projects are those that may be performed in the next two to eight years concurrently with site remediation. Implementation of near-term restoration projects is important for several reasons. First, near-term restoration projects will contribute to the overall objectives of site restoration by providing a mosaic of habitats at different stages of maturity. Second, staggering area-specific restoration projects over a number of years will more evenly distribute the funding to meet the overall sitewide restoration goals. Near-term restoration also allows for certain areas to benefit much sooner than they would if only postremedial restoration was undertaken. Figure 3-1 defines the extent of each project described below, with more detail provided for each project in Figures 3-2 through 3-6.

3.1.1 Aesthetic Barriers along Willey Road and S.R. 126

~~This near-term restoration project involves the use of earthen berms and tree plantings to provide a visual buffer between public roads and OSDF construction activities to the extent possible. A combination of coniferous and decidous tree species would be used to create a diverse habitat as well as an effective buffer. The support of a landscape architect would be contracted to design the appropriate barrier. A key consideration with this project would be to avoid creating a safety hazard along any of the local roads by restricting visibility or creating additional deer habitat to close to the road. These conditions could be avoided by leaving adequate space between the road and any trees that are planted. This project would be implemented in the Spring of 1998.~~

This near-term restoration project involves establishment of hedgerows using densely planted indigenous trees and shrubs that will provide both a visual buffer between public roads and OSDF construction activities and provide habitat for edge-dwelling wildlife (Figures 3-2 and 3-3). Effective visual screening will be achieved through dense planting of indigenous evergreens and hardwoods with dense twig structure. The aesthetic barriers will appear as natural hedgerows typical of rural roadsides in agricultural landscapes. This project will result in the restoration of approximately 1.3 acres. This area would be part of restoration required to compensate for impacts to grasslands (table 3-1).

3.1.1.1 Functional Objectives for Aesthetic Barriers

The functional objectives for the aesthetic barriers are immediate visual screening, aesthetic appeal and habitat for edge-dwelling wildlife. To provide immediate visual screening, a single row of white pines will be planted along the back line of the hedgerow. The hedgerow will consist of indigenous evergreens (Virginia pine, eastern red cedar), indigenous densely twigged hardwoods (e.g., honey locust, black willow, hawthorns) and other hardwood trees (e.g., red oak, common hackberry, green ash, eastern redbud). The hedgerow will also consist of shrubs (common elderberry, southern arrowood, tall deerberry) interplanted within the trees.

Aesthetic appeal will be provided by using spring flowering trees (e.g., Eastern redbud, American crabapple) and trees with vivid yellow and red fall foliage (e.g., red maple, black cherry, honeylocust, tulip poplar).

Edge-dwelling wildlife habitat will be provided by planting indigenous hedgerow trees and shrubs which contain a mixture of wildlife food sources, such as, berries and fleshy fruits (e.g., black cherry, common elderberry, tall deerberry, common hackberry), dry fruits (e.g., red maple, green ash), nuts (e.g., red oak), and pods (e.g, honeylocust, eastern redbud). By designing the hedgerow to include a mixture of trees and shrubs, conifers and hardwoods, and plants with various fruits, the hedgerow will provide quality habitat to wildlife species.

3.1.1.2 Design Considerations for the Aesthetic Barriers

To provide immediate visual screening, a single row of 2-inch caliper nursery stock balled and burlapped white pines will be planted on 10-foot centers along the back line of the hedgerow. The hedgerow will consist of planting four additional rows of hedgerow trees on staggered 10-foot centers. The hedgerow along Willey Road will be approximately 50 feet wide at planting and 55 feet wide at maturity, while the hedgerow along S.R. 126 will be approximately 30 feet wide at planting and 35 feet wide at maturity. The hedgerow will consist of 33 percent indigenous evergreens (Virginia pine, eastern red cedar), 33 percent indigenous densely twigged hardwoods (e.g., honey locust, black willow, hawthorns) and 33 percent of other hardwood trees(e.g., red oak, common hackberry, green ash, eastern redbud). The hedgerow will also consist of one-gallon container-grown shrubs (common elderberry, southern arrowood, tall deerberry) interplanted on staggered 10-foot centers to create an effective woody plant grid of 5-foot centers from the trees.

A key consideration in the design of visual buffers is the safety hazard which can be created by restricting visibility or creating additional deer habitat too close to the road. These conditions will be avoided by setting the barrier back at least 50 feet from the edge of the roadway. This project is proposed for implementation in the Fall of 1998.

3.1.2 Demonstration Forest Project West of Paddys Run

This demonstration project involves the creation of native forest cover in the grazed pasture located in the northwestern corner of the FEMP, west of Paddys Run (Figure 3-4). In addition, the riparian corridor adjacent to Paddys Run will be expanded from the northern property line to a point south of the K-65 silos. The purpose of this project is to provide an area of finished reforestation early in the overall restoration process that will effectively demonstrate to the public the feasibility and advantages of restoring natural habitats. The use of larger planting stock such as 1-inch caliper balled and burlapped trees would be recommended for this demonstration area to provide an immediate visible effect. The demonstration forest will provide upland and riparian habitat, and provide ecotones for many forms of wildlife. The grazing lease in this area will be terminated, as part of the continued phase-out of grazing lease agreements at the FEMP. The lessee will be notified in advance of the termination schedule. This project is scheduled for implementation in Fall 1999.

3.1.2.1 Functional Objectives for Demonstration Forest Project

This forested area will be one of the first to be revegetated and will serve as a demonstration project for restoration. This project will provide a sample of the types of restoration projects that will occur over the next several years. The functional objective is to provide habitat, serve as a buffer, and provide aesthetic appeal. This project will consist of two forest types, beech-maple and riparian forest. The beech-maple forest would be located along a portion of the north property boundary and the west property boundary, extending southward to the rail spur. The riparian forest would extend along the existing riparian corridor of the west bank of Paddys Run from the northern property line southward to approximately the K-65 silos and would provide additional habitat for the Indiana Bat. The Demonstration Forest Project will encompass approximately 28.6 acres in the northwestern part of the site. This project will be part of the required restoration for impacts to the Paddys Run Corridor (Table 3-1).

3.1.2.2 Design Considerations for Demonstration Forest Project

The beech-maple and riparian forest will be planted in a random patch design toward the goal of a target density of vegetation within a specified area. The target density will be typical of the local area. This methodology will be implemented within other restoration project areas where applicable.

The beech-maple forest will be typical of a Midwestern upland successional forest. It will consist of a canopy and shrub layer by randomly planting hardwood trees and shrubs. Trees would consist of a combination of 1-inch caliper balled and burlapped stock and seedling whips, while shrubs would consist of a combination of 2-gallon and 1-gallon container-grown stock.

Approximately 75 percent of the dominant tree species would consist of sugar maple, American beech, and tulip poplar, while the other 25 percent of associate tree species would consist of white ash, red oak, Ohio buckeye, black walnut, and red maple. Shrubs would consist of eastern redbud, flowering dogwood, Southern arrowood, mapleleaf viburnum, and common deerberry.

The riparian forest will be typical of a plant community found in somewhat poorly drained soils. This forest will consist of a canopy and shrub layer of plant materials which have root systems that are tolerant of prolonged moisture. Trees would consist of a combination of 1-inch caliper balled and burlapped stock and seedling whips, while shrubs would consist of a combination of 2-gallon and 1-gallon container-grown stock.

Approximately 75 percent of the dominant tree species would consist of red maple, shagbark hickory, box elder, pin oak, green ash, and American sycamore, while the other 25 percent of associate tree species would consist of Eastern cottonwood, slippery elm, swamp white oak, and blackgum. Shrubs would consist of common spicebush, common elderberry, rough-leaved dogwood, and Southern arrowood.

3.1.3 Revegetation of Area 2, Phase I

The remediation of Area 2, Phase I will result in a significant change in the topography of this area. The current Inactive Flyash Pile and Active Flyash Pile will be removed which will result in a decrease of the existing elevation. Because that area is adjacent to Paddys Run Stream, the proposed restoration would involve revegetating this area in a manner that will expand the riparian corridor along Paddys Run and protect and stabilize the stream bank of Paddys Run if necessary. In addition, the sediment ponds that are currently proposed for use during remediation may be relined and left in place to control sediment loading to Paddys Run (Figure 3-5). The remediation of Area 2, Phase I is expected to be completed in the year 2000. Therefore, revegetation efforts will be targeted for implementation in the Spring of 2001. This project will encompass approximately 20 acres immediately east of Paddys Run. This project, in conjunction with Project I, will constitute the required restoration for impacts to the Southern Pines and Wast Units (Table 3-1).

3.1.3.1 Functional Objectives for Revegetation of Area 2, Phase I

The functional objectives for Area 2, Phase I are to protect and stabilize the Paddys Run bank, if necessary, and to enhance the riparian corridor. Bank stabilization provides erosion control, additional instream cover, and helps maintain a natural meander. Bank stabilization techniques would include the use of natural erosion control devices such as coconut logs to control bank stability and serve as medium for planting. Bank protection can be effective and beneficial to aquatic communities by planting aquatic vegetation near the shoreline to stabilize the channel bed and protect undercutting of the embankments. Marginal plants can be used to protect those areas that are temporarily wet. Banks are stabilized by using vegetation with rapid growth such as willow.

Enhancement of the riparian corridor would increase water quality and reduce erosion. In low-order streams such as Paddys Run, riparian vegetation provides shading that reduces water temperature, discourages eutrophication, and provides organic material in the form of detritus, which is important for the health of the stream.

3.1.3.2 Design Considerations of Revegetation of Area 2, Phase I

To provide bank stabilization for areas disturbed during remediation, cuttings of native riparian trees and shrubs such as black willow, river birch, basket willow, and red-osier dogwood would be used. Cuttings would be densely planted on unforested bank areas. The exposed areas of the stream bank would be temporarily stabilized by seeding annual grasses with a straw mulch covering to allow the cuttings to develop adequate root systems. Once the cuttings are established they will develop into a few large trees and shrubs whose root systems will provide a more permanent stabilization of the streambank.

Log deflectors, which consist of logs, brush, and other natural materials, would be placed at the bottom of the eroding banks to deflect the current inward, reducing bank erosion. The log piles would provide cover for riparian wildlife and assist in the cooling of underlying pools of water. Coconut logs consist of coconut husks cylindrically shaped to a diameter of 8"-18" to allow the planting of riparian tree plugs. Coconut logs would be securely placed within the banks to reduce erosion and provide valuable riparian habitat.

Areas of the riparian corridor which are bare will be restored to riparian forest. Topsoiling will be necessary wherever natural surface soils have been eliminated by soil excavation. Exposed subsoils will be chiseled followed by application of topsoil to areas expected to be vegetated. Topsoil will preferably be obtained from nearby stripped areas. Such topsoil will serve as a reservoir of mycorrhizae, which are symbiotic fungi that enhance the establishment and growth of most vegetation. Topsoil will also contain propagules of weeds which are endemic to the region. If only a small supply of recently stripped topsoil is available, it can be mixed into a stockpile with commercial topsoil to inoculate the topsoil with mycorrhizae.

If a light-textured soil remains after remediation, a few inches of topsoiling may be adequate, otherwise 15-18 inches of topsoil and other light-textured soil may have to be added. Tree and shrub species would be randomly planted. Dominant hardwood trees would consist of red maple, American beech, box elder, black willow, pin oak, green ash, and American sycamore. Associate tree species would consist of Eastern cottonwood, slippery elm, swamp white oak, and blackgum. Shrub species would consist of rough-leaved dogwood, burningbush, common buttonbush, silky dogwood, common spicebush, and Southern arrowood. The enhancement of the Area 1, Phase I Woodlots will encompass 48.7 acres. This project, in conjunction with part of Project E, will constitute the required restoration for impacts to the Northern Woodlots (Table 3-1).

3.1.4 Enhancement of Area 1, Phase I Woodlots

~~This project involves the implementation of improvements to the northern pine plantation to restore native vegetation and enhance wildlife habitat (Figure 3.3). The rows of Austrian pines will be cleared and replanted with deciduous vegetation. Rows of white pines will be thinned according to established practices and replaced with native plant species that will provide food to wildlife. Non-native and/or invasive vegetation (e.g., multiflora rose, honeysuckle spp., wild grape) will be removed. In addition, openings will be made to diversify habitat and allow brush piles and snags to be created in the Area 1, Phase I (i.e., northern) woodlots. These woodlot will be enhanced through removal of non-native and/or invasive vegetation (multiflora rose, honeysuckle spp., wild grape).~~

~~Some areas of the Area 1, Phase I woodlots will be subjected to construction activity and related impacts since the area is adjacent to the OSDF. Therefore, the near-term activities discussed above will improve the survivability of the remaining stand of trees, provided that certification in this area does not indicate the need for excavation. Also, improved woodlots within Area 1, Phase I, will contribute to the long-term goal of establishing wildlife corridors at the FEMP.~~

This near-term restoration project involves the conversion of the Northern Pine Plantation to a beech-maple deciduous forest, transitioning to a oak-hickory deciduous forest on the northern slope, by interplanting hardwoods among the pines and thinning the pines as the hardwoods establish in size (Figure 3-6). The existing stand of hardwoods in the northern portion of Area 1 would remain unchanged. Hardwood planting sites would be formed by girdling and/or removing individual pines, which will result in small openings of filtered sunlight. Planting will be maximized in existing areas of localized sunlight caused by declining Austrian pines infected with Diplodia tip blight. Oak-hickory forest species will be interplanted throughout the successional hardwood forest on the northern slope of the existing pine plantation, which will encourage the conversion to mature oak-hickory forest. Non-native and/or invasive vegetation (e.g., multiflora rose, honeysuckle spp., wild grape) will be removed. In addition, openings will be made to diversify habitat and allow brush piles and snags to be created in the Area 1, Phase I (i.e., northern) woodlots. In some cases, portions of Austrian Pines will be completely removed to create stands of exclusively hardwoods or openings. Openings will be chanced with brush piles using cut trees.

Some areas of the Area 1, Phase I woodlots will be subjected to construction activity and related impacts since the area is adjacent to the OSDF. Therefore, the near-term activities discussed above will improve the survivability of the remaining stand of trees, provided that certification in this area does not indicate the need for excavation. Also, improved woodlots within Area 1, Phase I, will contribute to the long-term goal of establishing wildlife corridors at the FEMP.

The enhancement of the Area 1, Phase I woodlots will encompass 48.7 acres. This project, in conjunction with part of Project E, will constitute the required restoration for impacts to the northern woodlots (Table 3-1).

3.1.4.1 <u>Functional Objectives for Area 1, Phase I Woodlots</u>

The functional objectives are the establishment of deciduous forest communities and to provide wildlife habitat. Forest communities will be established by the conversion of the pine plantation into a beech-maple forest association and the transition to an oak-hickory forest association to the north. Plant species selected for the beech-maple portion will be typical of gently sloping areas with deep, rich, mesic soils. Plant species selected for the oak-hickory portion will be typical of drier slopes and ridges.

Wildlife habitat will be provided for interior forest species upon maturation. Prior to maturation of the proposed forest communities, the mosaic of existing forest cover combined with patched plantings of herbaceous vegetation and tree seedlings will provide good habitat for edge-dwelling forest wildlife.

3.1.4.2 Design Considerations for the Area 1, Phase I Woodlots

The conversion of the pine plantation into a beech-maple forest will require selective thinning of the existing rows of white and Austrian pines to promote pine canopy openings for the planting of hardwoods. Rows of both Austrian and white pines in the northern portion of the area will be thinned and enhanced with oak hickory plantings (e.g., red oak, scarlet oak, shagbark hickory). In the middle and southern portions of Area I, existing rows of pines would also be thinned and enhanced with beech-maple plantings (e.g., sugar maple, American beech, spicebush, and Atlantic leatherwood). Trees and shrubs more tolerant of filtered shade include white ash, Northern red oak, Southern arrowood, and flowering dogwood would be planted in areas where dense stands of pines will be left. Follow-up observations will be made regarding survivability. If low survivability is observed, then additional Austrian pines would be selectively thinned as necessary to allow more sunlight and new seedlings of the same species would be planted.

The ~~timing of~~ schedule for enhancing the Area 1, Phase I woodlots will be dependent upon the timing of remedial action certification for the area. Certification of ~~the northern woodlots could occur in 1998, with revegetation starting later that same year~~ Area 1, Phase I will be complete in 1997, however construction activities associated with the on-site disposal facility in this area will continue through 1998. Therefore, revegetation and enhancement will be implemented in Spring 2002 to ensure no additional laydown construction areas are planned for this area.

3.1.5 Enhancement and Management of Area 1, Phase III Woodlots East of Paddys Run

This ~~near-term~~ restoration project involves the enhancement and expansion of a large (approximately 100 acre) woodland, which will ~~and introduced grassland area The timing of the restoration project takes advantage of The accelerated certification of Area 1, Phase III provides a timely opportunity to create a continuous woodland habitat, interspersed with restored grasslands and to~~ increase habitat (and subsequently wildlife) diversity (Figure 3-7).

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~~Actions to improve the Area 1, Phase 3 woodlots will be conducted in the following manner.~~ The improvements to the Area 1, Phase III woodlot will be implemented in the following sequence. First, the grazing lease will be terminated, as part of the continued phase-out of grazing lease agreements at the FEMP. The lessee will be notified in advance of the termination schedule. Economic impacts to the lessee may be mitigated by the continuance of lease agreements west of Paddys Run for several years following the termination of the Area 1, Phase ~~3~~ III lease.

~~The next action will be the removal of non native and/or invasive vegetation (multiflora rose, honeysuckle spp., wild grape). In addition, introduced grasses will be cleared using mechanical and/or chemical means. Care will be taken to avoid impacts to the wetland mitigation efforts underway immediately south of the restoration area.~~

A comprehensive revegetation program will ~~be initiated in the year 2000. This effort will~~ be implemented in Spring 2002 and involve the connection of fragmented woodlots with native deciduous tree species. Most of the upland areas already support deciduous forest. The existing forest cover will be preserved, with the larger gaps being filled by planting tree seedlings as necessary and allowing natural succession to proceed toward climax forest. ~~In addition, revegetation will be utilized to expand the Area 1, Phase 3 riparian corridor west of Paddys Run. An upland tallgrass prairie system will then be established within certain cleared introduced grassland areas. This prairie system will be managed to prevent invasion of woody species.~~

This project will encompass approximately 103 acres of the northern woodlots. A portion of this project, in conjunction with Project D, will constitute the required restoration for impacts to the northern woodlots. Part of this project will contribute to the required restoration of the grasslands and the Great Miami River (Table 3-1).

3.1.5.1 Functional Objectives of Woodlot East of Paddys Run

The enhanced forest cover will provide a significant block of closed canopy forest to provide suitable habitat for interior forest dwelling wildlife.

3.1.5.2 Design Considerations for Woodlot East of Paddys Run

The termination of grazing is required to facilitate the progress of natural succession. Gaps in forest cover will be identified and planted using tree and shrub seedlings. Tree seedlings randomly planted will consist of Northern red oak, chestnut oak, shagbark hickory, scarlet oak, sugar maple, American beech, white ash, and Ohio buckeye. Shrub seedlings randomly planted will consist of mapleleaf viburnum, Eastern redbud, flowering dogwood, and common deerberry.

Existing areas of hardwood forest would be inspected for shrub development. In areas with little or no shrub development under the tree canopy, shrubs of the above listed species could be randomly planted. These shrubs are capable of growing in filtered shade. Physical removal of invasive or exotic vegetation would only include circumstances where stands of species such as Japanese honeysuckle are jeopardizing the survival of woody seedlings. In such cases, hand removal or hand application of herbicides would be performed.

3.1.36 ~~Wetland Mitigation within Area 1, Phase III~~ Expansion of the Northern Forested Wetland

Approximately 10 acres of jurisdictional wetlands will be dredged or filled as a result of remedial activities at the FEMP. In June 1995, DOE met with U.S. EPA, Ohio EPA, U.S. Fish and Wildlife Service, and the Ohio Department of Natural Resources to discuss mitigation of the impacted wetlands. DOE agreed to mitigate wetlands at a 1.5 to 1 ratio, replacing 1.5 acres of wetlands for every one acre dredged or filled. DOE also agreed to implement the mitigation on property if possible. To meet those two ~~stipulations~~ commitments, DOE has proposed the expansion of the northern forested wetland (Area 1, Phase III), if feasible (Figure 3-8).

A watershed study was conducted in 1996 to determine whether the hydrological conditions could support 15 acres of mitigated wetlands. Preliminary results of this study revealed some uncertainties as to whether the entire 15 acres can be ~~created~~ supported in this area, although some expansion does seem feasible. The precise amount of wetland acreage that can be supported in that area will be determined during conceptual design. The watershed study will be submitted to the above mentioned agencies and the Fernald ~~NRTs~~ Natural Resource Trustees ~~in parallel with the SEP~~ for review in parallel with the SEP. It is anticipated that a meeting to discuss the path forward of on-property wetland mitigation will be held in ~~Spring~~ Late Summer 1997. If determined appropriate ~~by the outcome of~~ during that meeting, DOE will initiate the design process for ~~on-property~~ expansion of the northern forested wetland as part of on-property mitigation with the goal of field implementation by ~~June 1999~~ Spring 2003.

~~A key milestone for wetlands creation in Area 1, Phase 3 is the certification of the area prior to field implementation. Unlike the Area 1, Phase I woodlots, certification scheduling may require modification to accommodate near term restoration. Specifically, certification of Area 1, Phase 3 must be accelerated to 1998. The entire area must be certified in order to accommodate drainage of the watershed into the wetlands.~~

Wetland mitigation in Area 1, Phase III can only be implemented after the area is certified, and the entire area must be certified in order to accommodate drainage of the watershed into the wetlands. Certification scheduling of Area 1, Phase III will need to be accelerated to accommodate near-term wetland mitigation.

3.1.6.1 Functional Objectives for Expansion of Northern Forested Wetland

The functional objectives for wetland mitigation are to meet the mitigation ratio and to provide wildlife habitat. The wetland mitigation ratio of 1.5:1 will be met if 15 acres of somewhat poorly drained soils can be formed within Area 1, Phase III. The temporary presence of a haul road through this area will reduce the amount of acreage available for near-term wetland mitigation. Upon removal of this haul road, more acreage would be available in this area for future implementation of wetland mitigation.

The proposed area for wetland mitigation is located south and adjacent to the Northern Woodlot which contains a contiguous and diverse mosaic of forest cover which provides good habitat for forest-interior dwelling wildlife. Wetland mitigation performed south of the Northern Woodlot would consist of a palustrine forested, broad-leaved deciduous wetland, which would provide additional habitat for interior forest dwelling species.

3.1.6.2 Design Considerations for Expansion of Northern Forested Wetland

Soils in the existing wetlands are mapped in the Ragsdale and Fincastle soil series and soils in the proposed wetland mitigation area are mapped in the Fincastle and Xenia soil series. The Ragsdale, Fincastle, and Xenia soils represent a catena of soil series that are of similar mineralogy but have different drainage classifications. The Ragsdale series consists of very poorly drained soils typically found in depressional areas and shallow basins. The Fincastle series consists of somewhat poorly drained soils, often in intermediate landscape positions between Ragsdale and Xenia soils. The Xenia series consists of moderately well drained soils, often found upslope of Fincastle soils. A detailed analysis of the soil and hydrological conditions in this area would be required to determine the suitability of wetland formation.

The successful establishment of wetland soils will involve ensuring the bottom of the wetland area contains impermeable material. Most of the proposed area for wetland mitigation is mapped as containing Fincastle soils with 0-2 percent slopes, which indicates these soils experience brief seasonal periods of poor drainage. The conversion of areas containing Fincastle soils may only require shallow surface excavation (4-6 inches) or it may be possible to form wetland conditions by compacting the soils without excavating. If excavation is performed, the excavation would be conducted so that the surface is no more than 12 inches above the seasonal high water table. Liners could also be utilized as determined appropriate. Water tables within approximately 12 inches of the surface in most fine textured soils will create a capillary fringe which saturates the surface. During excavation, silt fences would be established to separate the mitigation area from existing wetlands to prevent sediment deposition into the new wetlands until vegetation is established. Soil from the A-horizon will be stockpiled on nearby uplands to topsoil the new wetlands after excavation is complete. It may be necessary to overexcavate by 4-6 inches to provide adequate volume for topsoil.

Topsoiling involves the manipulation of the surface soil following excavation to form a suitable medium for plant establishment. In natural soils, the upper soil layer (A-horizon) is typically comprised of a surface layer of friable, loamy, dark colored soil underlain by a layer of similar material which is light yellow or orange. The A-horizon is generally 8-12 inches deep in both Fincastle and Xenia soils. Underlying the A-horizon is the B-horizon, which is mineral soil that is more dense and of greater concentration of aluminum and iron.

The best source of available topsoil for this wetland mitigation project would be from the stripped topsoil of the wetland mitigation area, if this soil is certified as clean. Such topsoil would contain a bank of native wetland plant propagules (seeds and rhizome fragments), along with native mycorrhizal fungi, which are symbiotic soil fungi essential to the growth of many plants. Although the propagule bank will be derived from uplands, many of the plants typical of low-lying uplands are also typical of seasonally saturated wetlands (red maple, Southern arrowood). Propagules capable of establishment in the wetlands will survive while the others will perish. If Phragmites australis, an invasive weed of wetlands and low-lying areas, is present in the stripped topsoil, then off-site sources, such as nurseries, may have to be considered for topsoil.

The mitigated wetlands will initially support woody seedlings amid a cover of emergent herbs typical of wet meadows. Revegetation will involve stabilizing the exposed wetland soils with a seed mix of native wetland grasses, sedges, and forbs, followed by the planting of woody wetland tree and shrub seedlings. The species composition of the herbaceous layer will change over time due to natural succession and will eventually be shaded out by the growth of trees and shrubs.

A dense herbaceous cover would be rapidly established to prevent erosion of exposed soils and sedimentation from existing wetlands. A seed mix consisting of species which are indigenous to wet meadow habitats and provide value to wildlife, would be intermixed and broadcast. The seed mix would consist of rice cutgrass, prairie cordgrass, woolgrass, softstem bulrush, rattlesnake mannagrass, lake sedge, and redtop. This seed mix is commercially available and is recognized for establishing a dense cover within a moderate time frame.

Woody tree and shrub species would then be randomly planted with the intent to establish forest cover. These species would be typical of seasonally saturated wetland forests and well drained riparian uplands. Tree species may consist of red maple, eastern cottonwood, green ash, American sycamore, black gum, box elder, and swamp white oak. Shrub species may consist of spicebush, buttonbush, common winterberry, common elderberry, and southern arrowood.

3.1.7 Near-Term Restoration Project Schedules

The schedules outlined in the table below have been developed in order to accomplish restoration as soon as practicable after remediation. The datas provided are not intended to be enforceable milestones, but rather target dates that will be dependent upon the completion of remediation commitments. Changes in the completion of remediation for these areas may cause adjustments in design submittals and project implementation which will be addressed as necessary in later version of this plan.

Near-Term Restoration Project	Design Submittal	Project Implementation
Aesthetic Barriers	Fall 1997	Spring 1998
Demonstration Forest Project	Summer 1998	Spring 1999
Revegetation of Area 2, Phase I	Spring 2000	Spring 2001
Enhancement of Area 2, Phase I Woodlots	Spring 2001	Spring 2002
Enhancement and Management of Area 1, Phase III Woodlots	Spring 2002	Spring 2003
Wetland Mitigation	Winter 2002	Spring 2003

3.2 Long-Term Restoration Projects

Long-term restoration projects will be implemented as soil remediation is completed and areas are regraded to support restoration. The extent of the restoration projects and their relationship with remediation at the site is depicted in Figure 3-9. In addition, Figures 3-10 through 3-12 provide more detail for each restoration project.

3.2.1 Open Water/Wetland Formation in the Former Production Area

The goal of restoring open water and wetland habitat is to provide varying depths of water to encourage diversity of species and feeding areas. Adequate hydrology must be available to sustain both open water and wetland habitat. The anticipated depth of excavation in the Former Production Area makes it a preferable location for the establishment of these habitats. The restorations of the Production Area will result in the formation of approximately 217 acreas of new habitat. While a portion of this project will contribute to required restoration for impacts to the Production Area, the majority of this project (197 acres) will contribute to required restoration for impacts to the Great Miami Aquifer through the preservation of groundwater recharge area (Table 3-1).

~~The goal of open water and wetland habitat would be to provide varying depths of water for diversity.~~ Open water habitat requires slopes of 3:1 or higher to a depth of 8 to 20 feet with soils containing textured and silty clays. Wetlands generally require gradual shoreline slopes of 6:1 or flatter to a depth of 1 to 3 feet to encourage species diversity and feeding areas. Poorly drained soils are required to provide an impermeable substrate for sustaining anaerobic soil conditions for 15-21

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consecutive days during the growing season. Grading and appropriate outflow structures should direct drainage to the south through the Storm Sewer Outfall Ditch.

As part of design, a detailed hydrological analysis will be performed to determine how much water is available to support permanent inundation for open water habitat. A tall grass prairie and wet meadow mosaic would be an alternative to a permanently inundated open water habitat.

The tallgrass prairie would be dominated by indigenous prairie grasses and prairie forbs. The wet meadows would be created within shallow post-excavated depressions and would be dominated by indigenous wetland grasses and forbs. The entire grassland complex would be surrounded by forest, with an ecotone of savannah habitat characterized by sparse deciduous tree cover undergrown by prairie grasses. The proposed 200-acre complex of tallgrass prairie and emergent wetlands would be one of the largest areas of tallgrass prairie in Southwestern Ohio and would be reminiscent of some of the largest grassed forest openings in Ohio's presettlement vegetation. The Ohio DNR has recently completed a similar mosaic in nearby Shawnee Park which consist of restored tallgrass prairie adjacent to emergent wetlands.

The area will undergo revegetation upon completion of open water/wetland formation to establish shoreline stability, appropriate habitat and desired diversity. Revegetation will include planting native hardwood tree species, and the possible establishment of shrubs such as blackberry, black raspberry, and silky dogwood as edge habitat to provide a transition zone. Wildlife boxes will be installed to promote bird and mammal habitation. Other possible features of these areas include trails, interpretive signs, observation decks and blinds.

3.2.1.1 Functional Objectives for Former Production Area

This project would contribute 216.9 acres of groundwater protection and would provide a portion of primary compensation for groundwater impacts. The HEA (Addendum A) accounts for other actions toward groundwater compensation such as the public water supply.

If adequate hydrology is available to support permanent inundation for open water habitat, this would provide excellent habitat for migratory waterfowl. If it is determined that the volume of water is inadequate to support permanently inundated open water habitat, a tallgrass prairie and wet meadow mosaic would be established to provide a natural landscape, grassland habitat, natural drainage, and aesthetics.

The most basic objective is to provide a natural and self-supporting vegetative cover. This area will be devoid of vegetation and topsoil following remediation and will resemble a strip mine. To establish vegetation which promotes high habitat and aesthetic value will require investigation of the surface soils which remain following remediation. Such an investigation will be necessary to design an effective program of topsoiling and soil amendments to ensure successful establishment of natural vegetation.

Providing grassland habitat will encourage wildlife in southwestern Ohio which once favored such openings. These species may include the bobolink, grasshopper sparrow, meadowlark, Henslow's sparrow and savannah sparrow. These species continued to thrive after human settlement on lightly grazed and infrequently mowed pastures in the agricultural landscape.

The wet meadows would increase habitat diversity within the tallgrass prairie by providing habitat for a diversity of waterfowl and several wading birds without interrupting the broad expanse of open grassland required by the grassland-dependent wildlife. These depressional wetlands will resemble prairie potholes, which were once common in larger prairie expanses further west.

A natural drainage system will be graded to provide a hydrologic connection between each wet meadow area. Run-off will be directed to the south to flow through wetland areas and into Paddys Run. Directing drainage to the south will also prevent excessive erosion because over time the drainage will revert to the pre-developed contours which indicate overland flow was to the south and into Paddys Run.

The tallgrass prairie would occupy the central portion of the site surrounded by a forested perimeter. Prairie grasses and forbs would provide an array of textures and colors throughout the year.

3.2.1.2 <u>Design Considerations for the Former Production Area</u>

This project involves creation of wetlands and possibly open waters and as such will require a detailed hydrological analysis to determine the type of aquatic habitats. Soil borings will be analyzed to characterize the soil profile underlying the proposed final grade. The physical and chemical properties of these soils will examined to support the design of a topsoil and soil amendment program. Specific sources of suitable topsoil will be identified before the design is finalized.

The final grade will be required to simulate the natural conditions necessary to create the tallgrass prairie-wet meadow complex. Standards for the reclamation of coal strip mines include restoring the mine headwall (the upper slope separating the mine from intact upland soils) to a slope not exceeding 3:1, and other slopes within the mine to less than 5:1. The former Production and Waste Pit areas may be more representative of conditions requiring a 5:1 slope. The 5:1 slope would represent an upper limit on steepness, with an emphasis on the formation of gently undulating topography where possible. Gentler slopes will facilitate revegetation, reduce the likelihood of gully erosion, and be more compatible with the surrounding landscape. The finished grade would direct surface runoff into distinct subwatersheds, which ultimately would drain into Paddys Run. The lowest lands of each subwatershed would contain a sequence of shallow depressions connected by a channel. The downstream end of each depression will be slightly bermed to induce wetland conditions. Linear swales will be formed to allow runoff within the swales to naturally carve the channels.

Following soil remediation the exposed subsoils will be chiseled followed by application of topsoil to areas expected to be vegetated. Topsoil would preferably be obtained from nearby stripped areas. Such topsoil will serve as a reservoir of mycorrhizae, which are symbiotic fungi that enhance the establishment and growth of most vegetation. Topsoil would also contain propagules of weeds which are endemic to the region. If only a small supply of recently stripped topsoil is available, it can be mixed into a stockpile with commercial topsoil to inoculate the topsoil with mycorrhizae.

Topsoiling to a depth between 4 and 10 inches may be required. Within this range, deeper topsoiling would be required for the forest savannah and shallower topsoiling for proposed areas of tallgrass prairie and wet meadow. No topsoiling would be placed in proposed areas of intermittent streams. These topsoiling recommendations will be more definitive upon characterizing the subsoils underlying the former Production and Waste Pit areas. The 4-inch topsoiling minimum assumes the subsoils are silty clay loams or lighter and they may be chiseled or disked prior to topsoiling. Otherwise, it may be necessary to establish a deeper topsoil layer, since plant roots will be permanently confined to that layer.

The tallgrass prairie may consist of a seed mix which contains Indian grass, big bluestem, little bluestem, side-oats gramma, and switchgrass. The seed mix would contain 2 pounds/acre pure live seed (lb/A PLS) Indian grass, 2 lb/A PLS big bluestem, 1 lb/A PLS little bluestem, 1 lb/A PLS side-oats gramma, and 0.5 lb/A switchgrass. The grass cover would be intermixed with forbs to provide a diversity of plant species. Forb species may include blackeyed Susan, prairie coneflower, lance-leaved coreopsis, lead plant, purple coneflower, prairie partridge pea, purple prairie clover, and prairie dock. The forb seed mix would be applied at a rate of 2-4 ounces per acre in addition to the grass seed. Since many prairie seed mixes contain native forbs, it may not be necessary to separately apply the forb mix. Depending upon the diversity of forbs established, it may be necessary to plant plugs or seedlings of one or more of the forbs species to ensure a good intermix of forbs. Tall fescue will not be seeded since this pasture grass is aggressive and tends to exclude other grasses of higher wildlife value.

The tallgrass prairie-deciduous forest savannah would be established in the same manner as the tallgrass prairie. The forest component would be established by random planting of tree seedlings. These species may include red oak, white oak, chestnut oak, shagbark hickory, shellbark hickory, tulip poplar, and sugar maple.

The wet meadow would contain a wet prairie seed mix which contains grass and forb species. Grass species would include big bluestem, blue-joint grass, switchgrass, prairie cordgrass, and Canada wild rye. Forb species would include swamp milkweed, boneset, sneezeweed, prairie dock, stiff goldenrod, prairie blazingstar, gray-headed coneflower, and bur marigold.

If hydrological conditions permit, certain depressions may contain a transition from shallow open water to seasonally inundated wetlands. The vegetation of seasonally inundated wetlands would consist of vegetation typical of pond edge habitats and tolerant of regular to permanent inundation up to 1 foot. Representative plant species may include water plantain, lake sedge, squarestemmed spikerush, mannagrass, pickerelweed, hardstem bulrush, and softstem bulrush. Cattails are not recommended since they are invasive and tend to form monotypic stands. If cattails do volunteer they would be eradicated if they began to excessively spread.

Shallow open water areas develop a nonpersistent perennial plant population which root in the bottom sediment and produce erect vegetative stalks during the growing season. The stalks of certain species remain submerged, forming an underwater forest, while the stalks of other species protrude above the water line, sometimes producing large floating leaves and flowers. The stalks die back and rapidly decompose prior to winter, resulting in areas of dense underwater and floating vegetation during the summer that revert to open waters during the winter. This type of wetland vegetation is nonpersistent in contrast to persistent wetland vegetation, where dead stalks protrude from the water year round.

Desirable plant communities of nonpersistent wetland vegetation can provide cover and food for aquatic wildlife and help to oxygenate the water and improve water quality. However, several species of aggressive, invasive nonpersistent plants can form dense mats of cover that can be detrimental to the aquatic community. Such invasive populations can impede movement of aquatic species, exclude light required by microscopic algae, and create large masses of dying vegetation in the fall which can reduce the water's oxygen levels, causing suffocation of most aquatic biota.

Nonpersistent plant species selected would be noninvasive plant species which are indigenous to southwestern Ohio in shallow open waters 3 feet in depth. These plant species include a mixture of species that produce submerged growth, emergent growth, and floating leaves which will maximize habitat diversity. Seedlings of at least one floating and one submerged species would be planted in equal proportions on approximately 3-foot centers in each area of open water. These species include fragrant water lily (floating), water smartweed (floating or emergent), widgeongrass (submerged), and wild celery (submerged).

Once the tallgrass prairie becomes established, it will become invaded with woody plants through natural succession. The prairie could be maintained by mowing the seeded prairie once in late summer in the year of establishment followed by periodic mowing once every 2 or 3 years to discourage woody volunteers.

Controlled burning is another method for maintaining prairies established for wildlife, provided the burns could be conducted safely. The burns simulate the original presettlement environment of the prairies and enhance growth of the grasses. Regularly mowed firebreaks between 30 and 50 feet in width, must be established around the area to be burned. A burning cycle at least once every 3 years would be conducted, extending the fire cycle may cause buildup of vegetation which results in a more intense burn that damages the grass root systems. The centralized location of the tallgrass prairie-wet meadow complex should allow for the conduct of controlled burns with minimal impact to local residents.

3.2.2 ~~Formation of Open Water Habitat~~ Open Water/Wetland Formation in the Former Waste Pit Area

The same ~~considerations should be taken for open water habitat as described above~~ factors will be considered for restoration and revegetation of open water/wetlands as described in Section 3.2.1. However, the western edge of the waste pit area will require elevation with an earthen berm as part of final grading (Figure 3-9). This will provide sediment retention, minimize run-off into Paddys Run and will allow necessary hydrology for open water habitat. If feasible, drainage should be directed into the Former Production Area. Revegetation and other enhancement efforts would be implemented similar to that described for the former production area.

If the stream bed of Paddys Run is excavated during soil remediation, then stream restoration will be necessary. This will require restoration of the natural stream geometry, meander, and contour to areas disturbed by soil excavation. Natural substrate will be restored to disturbed areas in the stream channel to form a natural sequence of riffles and pools.

This project would contribute 72 acres of new habitat. A portion of this project would contribute to the restoration required for impacts to the Waste Pit Area. However, the remaining portion would provide a portion of the compensation for groundwater impacts (Table 3-1).

3.2.2.1 Functional Objectives of Instream Restoration

To successfully restore portions of the stream channel, the instream zone (that area which carries non-peak flows) must be returned to a natural configuration in conjunction with stabilization of the riparian corridor (as described in Section 3.1.4.2). The configuration would be capable of responding to continuous hydrodynamic change. Natural materials would be used to allow streambank erosion and accretion to proceed at natural rates. The restored stream would be designed with a natural meander pattern that simulates streambank erosion and accretion, and allows those processes to continually reshape and reconfigure the stream into the future.

Meandering is an important factor in stream channel morphology. Stream meandering is affected by hydrologic factors such as changes in stream flow and runoff. Hydrologic factors (depth, velocity, slope) directly control sediment transport and erosion of the stream bank. Pool and riffle formation are also controlled by hydraulic factors due to differential transport of sediments in terms of particle size and velocity.

3.2.2.2 Design Considerations for Instream Restoration

Channel restoration of the natural stream channel geometry would involve the formation of riffles and pools in the channel. Riffles are stretches of fast moving, shallow water flowing over a rocky substrate, and pools are stretches of deeper slow moving water flowing over a soft substrate. Alternating riffles and pools will provide diverse aquatic habitat and will provide natural stream flow patterns. Riffles would be formed by strategic installation of cobble clusters at sequential intervals in the stream channel. Pools would then result in the intervals between the riffles. Riffles will be formed by installing 4" diameter cobbles grouped together to form a riffle that is 40 to 60 feet in length, covering the entire width of the stream channel.

Log deflectors would be placed on the outside edge of channel meanders to deflect the current inward to reduce bank erosion. The log deflectors would also provide excellent cover for riparian wildlife and help to cool underlying pools of water.

3.2.3 ~~Revegetate Former Production and Waste Pit Areas~~ Phase II Expansion of Paddys Run Corridor to the West

~~Upon completion of open water/wetland establishment, the area will require revegetation in order to establish shoreline stability, appropriate habitat and desired diversity. Native hardwood species would be planted and wildlife boxes would be installed to promote bird and mammal habitation. Edge habitat will also be considered to allow a transition zone between habitat types. Shrubs such as blackberry, black raspberry and silky dogwood could be planted in alternating frequency in an effort to supply edge habitat. Other possible features of these areas could include the establishment of trails, interpretive signs, observation decks and blinds.~~

~~Complete expansion of the corridor will ensure a protected riparian habitat and formation of grassland habitat by enhancing vegetation to the west of the stream. Some improvements to Paddys Run could~~

~~also be considered to create additional pools, if determined appropriate. Cattle will also be removed from grazing activities in this area to allow habitats to form.~~

Expansion of the Paddys Run corridor will ensure a protected riparian habitat and formation of grassland habitat by enhancing vegetation west of the stream (Figure 3-10). Improvements may also be considered to create additional pools in Paddys Run, if appropriate. Grazing activities in this area will be terminated to allow habitats to form.

The expansion of the Paddys Run Corridor to the west will result in approximately 77 acres of enhanced habitat. The majority of this will contribute to required restoration for impacts to the Paddys Run Corridor (along with Project B). However, a portion of this project (approximately 29 acres) will compensate for impacts to the Southern Pines and waste units (Table 3-1).

Vegetation enhancement from the confluence of the Pilot Plant drainage ditch to the southern property boundary (approximately 800 feet) ~~would~~ will consist of randomly planting seedling and sapling tree species. ~~(black locust, silver maple, white ash) in alternating frequency.~~ Edge habitat ~~would be formed~~ will be established on the northern fringe of the riparian habitat to provide a transition into the grassland. Grassland habitat ~~would extend~~ will be established just North of the confluence of the Pilot Plant drainage ditch ~~south from the railroad~~ by planting a prairie seed mix consisting of grasses and forbs. Grasses consist of big blue stem, Canada wild rice, and Indian grass; some examples of forbs are New England aster, pale purple coneflower, oxeye sunflower, and black-eyed Susan. Legumes such as Canada milkvetch and Canada tick-trefoil will be planted to provide additional fertilization to adjacent plants. However, if a tallgrass prairie-wet meadow complex is established in the former production and waste pit areas, an abundance of grassland habitat would be provided. The proposed grassland area west of Paddys Run would become an upland forest area. Forested stream corridors are an important feature to the regional migration of forest and forest-edge wildlife. ~~by supporting colonies of microorganisms which fix nitrogen on their roots.~~

3.2.3.1 Functional Objectives for Phase II Expansion of Paddys Run Corridor to the West

Enhancement of the riparian corridor would increase water quality and reduce erosion. In low-order streams such as Paddys Run, riparian vegetation provides shading that reduces water temperature, discourages eutrophication, and provides organic material in the form of detritus, which is important for the health of the stream.

3.2.3.2 <u>Design Considerations for Phase II Expansion of Paddys Run Corridor to the West</u>
Tree and shrub species would be randomly planted. Dominant hardwood trees would consist of red maple, American beech, box elder, black willow, pin oak, green ash, and American sycamore. Associate tree species would consist of Eastern cottonwood, slippery elm, swamp white oak, and blackgum. Shrub species would consist of rough-leaved dogwood, burningbush, common buttonbush, silky dogwood, common spicebush, and Southern arrowood.

3.2.4 <u>Reestablishment of ~~Riparian~~ Corridor East of Paddys Run ~~Stream~~</u>
Stable banks along the east side of Paddys Run will be established ~~following the final grade~~ to near-original contours during the final grade (Figure 3-11). Bank stabilization will be accomplished by utilizing the same techniques as outlined in Section 3.1.5.2. ~~initially using grasses planting grasses, following by the planting of mature saplings. (black locust, silver maple, white ash) Additional topsoil and clay may need to be imported to support plant growth if excavations result in extracting necessary micro- and macronutrients. In addition, areas impacted from soil excavation during remediation of the waste pits and other waste units will be revegetated.~~

The Southern pine plantation will be converted into a beech-maple forest by selective thinning of the Austrian pines to promote pine canopy openings for the planting of hardwoods, as outlined in Section 3.1.5.2.

This project would contribute approximately 70.4 acres of groundwater protection and would provide a portion of compensation for groundwater impacts along with Projects G and H (Table 3-1). This project will provide protection of an important groundwater recharge zone for the GMA.

3.2.5 <u>~~Wetland Construction in~~ Borrow Area Wetland Construction/Edge Habitat Formation</u>
~~Constructing a Free Water Surface (FWS) wetland in the borrow area south of the OSDF will serve as a passive waste water treatment system for OSDF storm water.~~ ~~A Free Water Surface (FWS) wetland will be constructed in the borrow area south of the OSDF to serve as a wastewater treatment system for OSDF stormwater (Figure 3-12).~~ ~~With FWS wetlands, water flows primarily over the soil~~

~~substrate and through the plant zone. Depending upon the design and objectives of the system, FWS wetlands have the potential to assimilate BOD, TSS, Total Nitrogen, and Total Phosphorus.~~

The southeastern corner of the project area would be used to form habitat conducive to wildlife that prefers edge habitat, including forest-grassland, forest-old field, and wetland-upland edges. The positioning of small and narrow patches of forest, scrub-shrub, prairie, old field, and wetland habitat would maximize the amount of edge habitat present. Wetland(s) would be formed from the borrow area to further increase habitat diversity and provide wetland to upland edge habitat (see Figure 3-12). Many game species such as bobwhite quail, whitetail deer, ring-necked pheasant, eastern cottontail, raccoon, and wild turkey favor edge habitats which are also aesthetically pleasing.

This project would result in the formation of approximately 138.5 acres of new habitat. This project, along with Projects A, E, and L will provide the required restoration for impacts to the grasslands at the FEMP (Table 3-1).

3.2.5.1 <u>Functional Objectives for Borrow Area Wetland Construction/Edge Habitat Formation</u>

The functional objectives are the formation of a natural landscape, habitat for edge-dwelling wildlife, and aesthetic appeal. Restoring natural vegetation will be a key consideration. Investigation of the surface soils which remain following soil excavation will be necessary to design an effective program of topsoiling and soil amendments to ensure successful establishment of natural vegetation.

The formation of forest edge-habitat and wetland(s) will complement the other major habitat types on the site such as the open water habitat (if possible) or tallgrass prairie and emergent wetlands in the center of the site, a broad expanse of closed canopy forest across the northern part of the site, and fully restored riparian habitat on the west part of the site. The overall design of the southeastern corner would resemble a hunting preserve dedicated to game management.

The proposed mosaic of forest, old field, prairie, and wetland habitats will provide aesthetic appeal. The old field and prairie areas will support a diversity of colorful wildflowers and the old field areas and forest edges will support a diversity of spring flowering shrubs and shrubs with red fall foliage. The mosaic of contrasting vegetative cover will provide a high level of visual diversity over a small area.

3.2.5.2 Design Considerations for Borrow Area Wetland Construction/Edge Habitat Formation

A detailed hydrological investigation will be essential before a determination can be made regarding wetland formation. It will be necessary to analyze soil borings to characterize the profile of soil underlying the proposed final grade. The physical and chemical properties of these soils will be examined to support the design of a topsoiling and soil amendment program.

Wetlands generally require gradual shoreline slopes of 6:1 or flatter to a depth of 1 to 3 feet. The vegetation of seasonally inundated wetlands would consist of vegetation typical of pond edge habitats and tolerant of regular to permanent inundation up to 1 foot. Representative plant species may include water plantain, lake sedge, squarestemmed spikerush, mannagrass, pickerelweed, hardstem bulrush, and softstem bulrush. Cattails are not recommended since they are invasive and tend to form monotypic stands. If cattails do volunteer they would be eradicated if they began to excessively spread.

Shallow open water areas would consist of nonpersistent and noninvasive plant species which are indigenous to southwestern Ohio in shallow open waters 3 feet in depth. These plant species include a mixture of species that produce submerged growth, emergent growth, and floating leaves which will maximize habitat diversity. Seedlings of at least one floating and one submerged species would be planted in equal proportions on approximately 3-foot centers in each area of open water. These species include fragrant water lily (floating), water smartweed (floating or emergent), widgeongrass (submerged), and wild celery (submerged).

Old field vegetation will be established to stabilize exposed soils (if necessary) by randomly planting old field shrubs and allowing old field perennials to volunteer through natural succession. Tall fescue would not be used for stabilization purposes because it has allelopathic properties by which it secretes chemicals into the soil that discourage establishment of other species. The seed mix would contain grasses and legumes which consist of reed canarygrass, redtop, and birdsfoot trefoil. The legumes provide cover diversity and contribute nitrogen to the soils. Once the herbaceous cover is established, old field shrubs such as black cherry, black locust, staghorn sumac, cockspur hawthorn, prairie rose, and dwarf chinkapin oak would be randomly planted.

Narrow transition areas of old field scrub-shrub would be planted where old field is to abut oak-hickory forest. These transition areas would be seeded in a manner similar to adjoining areas of old field, but would be provided with a denser random planting of the above mentioned woody shrubs and tree seedlings.

The portion of open land which consists of tallgrass prairie would be planted in the same manner as described in Section 3.2.1.2.

Narrow transition areas of an ecotone of savannah habitat characterized by sparse deciduous tree cover undergrown by prairie grasses would be planted where tallgrass prairie is to abut beech-maple forest. The tallgrass prairie-deciduous forest savannah would be established in the same manner as the tallgrass prairie. The forest component of the savannah would be established by random planting of tree seedlings. These species may include red oak, white oak, chestnut oak, shagbark hickory, shellbark hickory, tulip poplar, and sugar maple.

The beech-maple and oak-hickory forests would be developed as outlined in Section 3.1.4.

3.2.6 ~~Establish Aesthetic Buffer Around OSDF~~ OSDF Aesthetic Buffer

The public has requested that a buffer be established around the OSDF to lessen visual impact of the facility. The buffer ~~could~~ will be established with appropriate topography and vegetation so that it will function as a wooded corridor habitat with conifers and prairie plants (Figure 3-9). Other possible features of this project include establishing areas of native grasses~~, establishing the maximum diversity on the OSDF without compromising integrity~~ and providing nest boxes for target species. The aesthetic buffer around the OSDF will add approximately 110 acres of new habitat. This project, along with Projects A, K, and portions of E, will compensate for the required restoration for impacts to Fernald grasslands (Table 3-1).

~~The goal of all OSDF associated restoration is to establish the maximum diversity on the OSDF without compromising its integrity.~~

Trees and shrubs would not be planted on the OSDF because their roots could breach the clay cap covering the disposal facility. Indigenous prairie grasses could be planted on the OSDF to provide additional habitat for prairie wildlife. The western perimeter of the OSDF would be comprised of riparian forest, which would convert the drainage ditch to a headwater stream of high habitat value. The eastern perimeter would contain a hedgerow, with the remaining portions of the perimeter containing beech-maple forest.

3.2.6.1 Functional Objectives of the OSDF Aesthetic Buffer

The functional objectives are to provide visual screening, edge habitat, and aesthetic appeal. The OSDF visual buffer will lessen the visual impact of the OSDF to the surrounding landscape. This buffer will not be able to completely obscure the 50-foot plus tall mound of earth which will comprise the OSDF, but the buffer will appear as a natural dense strip of woody vegetation which will soften the appearance of the mound. Selection of plant material will emphasize the use of indigenous evergreens and indigenous densely twigged hardwoods.

Edge-dwelling wildlife habitat will be provided by planting indigenous hedgerow trees and shrubs which contain a mixture of wildlife food sources, such as, berries and fleshy fruits (e.g., black cherry, common elderberry, tall deerberry, common hackberry), dry fruits (e.g., red maple, green ash), nuts (e.g., red oak), and pods (e.g. honey locust, eastern redbud). By designing the hedgerow to include a mixture of trees and shrubs, conifers and hardwoods, and plants with various fruits, the hedgerow will provide quality habitat to wildlife species.

Aesthetic appeal will be provided by using spring flowering trees and shrubs with vivid yellow and red fall foliage.

3.2.6.2 Design Considerations for the OSDF Aesthetic Buffer

The exposed surface soil will require investigation as to its ability to support vegetation. Compacted subsoil at the surface may need to be chiseled and covered with 4 to 10 inches of topsoil. However lighter subsoils that can be readily chiseled may successfully support trees and shrubs with only minimal topsoil application.

The riparian buffer areas would include four rows of 1-inch caliper trees planted on staggered 10-foot centers. Approximately 50 percent of the trees would be black willow and the remaining 50 percent of trees would be comprised of red maple, green ash, American sycamore, slippery elm, box elder, and eastern cottonwood. Shrubs would be installed in staggered rows on 20-foot centers using 1 gallon container-grown stock. Shrubs would consist of rough-leaved dogwood, common buttonbush, silky dogwood, common spicebush, and Southern arrowood.

The nonriparian buffer would consist of planting four rows of 1-inch caliper trees on staggered 10-foot centers. Tree species would consist of four species of the following hardwoods: black walnut, red maple, black maple, sugar maple, American beech, white ash, tulip poplar, red oak, Ohio buckeye, eastern redbud, and flowering dogwood. Shrubs would be planted in staggered rows on 20-foot centers using 1-gallon container-grown stock. Shrub species would consist of three species of the following: pagoda dogwood, staghorn sumac, Southern arrowood, mapleleaf viburnum, and common deerberry.

To provide immediate visual screening along the east perimeter, a single row of 2-inch caliper nursery stock bailed and burlapped white pines will be planted on 10-foot centers along the back line of the hedgerow. The hedgerow will consist of planting four rows of 1-inch caliper hedgerow trees on staggered 10-foot centers. The hedgerow will consist of 33 percent indigenous evergreens (Virginia pine, Eastern red cedar), 33 percent indigenous densely twigged hardwoods (e.g., honey locust, black willow) and 33 percent of other hardwood trees (e.g., red oak, common hackberry, green ash, Eastern redbud). The hedgerow will also consist of one-gallon container-grown shrubs (prairie rose, common deerberry, Southern arrowood, common elderberry) interplanted on 10-foot centers between tree rows.

4.0 MONITORING

4.1 Remedial Action Monitoring

Monitoring for habitat impacts will be conducted during the implementation of remediation activities (Natural Resource Impact Monitoring Plan) (Figure 1-2). Field monitoring and reporting will be conducted every 2.5 months in accordance with the IEMP quarterly monitoring reporting. Results of monitoring will be compared with the magnitude of impacts outlined in the NRIA to determine unanticipated impacts during remediation and provide needed adjustments to restoration activities. Monitoring results and subsequent adjustments to the HEA and NRRP will be presented in future updates of this plan pursuant to Section 2.2.1.

~~Field measurements of the impacted area(s) will be taken to obtain approximate acreage of impact. Smaller impact areas will be measured by hand using a 300 foot measuring tape, while larger impact areas will be surveyed using field verification methods.~~ Field measurements of the impacted area(s) will be taken of the impacted area(s)to the acreage of impact using a geographic positioning system backpack unit. Areas of impact will be documented within a database indicating the associated activity and field observations, and photographs will also be taken. In addition, a map will be scaled to depict the acreage of habitat areas and types to display the status of habitat impacts. Various hatched solid block designations would show habitat types and associated acreage. As habitat types are impacted, the hatching would be removed to show habitat status.

~~Results of monitoring will be compared with the results of the natural resource impact assessment to determine unanticipated impacts during remediation and provide needed adjustments to restoration activities and presented in future updates of this plan.~~

4.2 Success Monitoring of Restored Natural Resources

Success monitoring will be implemented to ensure that all restored habitats functioned as planned. The specific criteria for success monitoring would be established in conjunction with detailed project design. ~~This section will be expanded in later versions of this plan to define specific monitoring methodology.~~ Another function of success monitoring is verification and comparison of planned restoration acreage from the NRRP to restoration implemented in the field. This section will be updated in each revision of the NRRP to report the results of success monitoring. The detailed success monitoring methodology will be outlined in the design of each project.

5.0 STAKEHOLDER INVOLVEMENT

Stakeholder involvement will be essential to successful development and implementation of this restoration plan. All meeting summaries generated from Natural Resource Trustee Meetings are made available to the public. In addition, a workshop(s) ~~would~~ will be planned with the public to discuss the proposals in the restoration plan for final land use upon approval of the NRRP by the agencies and Natural Resource Trustees. Stakeholder input will be essential throughout the development and implementation of this plan.

6.0 INSTITUTIONAL CONTROLS AND FUTURE LAND USE

~~One element of the Operable Unit 5 selected remedy that will be used to ensure protectiveness is institutional controls, including;~~Institutional controls are established in the Operable Unit 5 selected remedy as a means of ensuring continued protection of human and ecological receptors. These include:

- Continued access controls at the site during the remediation period
- Alternate water supplies to affected residential and industrial wells
- Continued federal ownership of the ~~disposal facility and necessary buffer zones~~ FEMP property
- Deed restrictions necessary to preclude residential and agricultural uses only and ensure recreational use of the remaining areas of the FEMP property
- Application of conservation easements for habitat restoration~~, and~~
- Enhancement of off-property areas, and the possible purchase of additional property adjacent to the FEMP.

Additionally, proper notifications, as mandated by CERCLA, will be provided before the transfer of any federal real property known to contain, or ~~have been~~ used in the processing of, hazardous substances. These measures will minimize the potential for human exposure to contaminated soil and groundwater during the implementation of sitewide remedial actions, and to the contaminated material contained in the ~~on-property disposal facility~~ OSDF following completion of remedial activities at the site. Specific institutional control measures will be established during the remedial design and remedial action processes. This section will be expanded as detailed design of specific projects are completed and the details of necessary institutional controls are identified. Once finalized, this plan will function as the Institutional Control Plan and Future Land-Use Plan for the site.

The Fernald Citizens Task Force issued recommendations regarding future use of the FEMP property in May 1995. The Task Force recommended that the ~~are~~ area of the FEMP containing the disposal facility and associated buffer zone remain under the continued ownership of the federal government. Additionally, the Task Force recommended that the remaining portions of the FEMP property be made available for the uses deemed most beneficial to the surrounding communities. The Task Force encouraged DOE to consult with the local communities to establish their preferences for future use and ownership of these areas of the site. Consistent with these recommendations, the DOE will work with the local communities during remedial design on establishing a final land use and ownership plan for the FEMP property. An institutional control plan, focused on specifying the short-term (i.e., during remedial implementation) and long-term institutional control measures to be applied at the site, will be developed during remedial design to complement this final land use plan. The following key components are identified for institutional controls and monitoring:

- Continuation of access controls at the FEMP, as necessary, during the conduct of remedial actions. Property ownership of the disposal facility and associated buffer areas will be maintained by the federal government.

- Maintenance of remaining portions of the FEMP property (outside the ~~disposal facility~~ OSDF area) under federal ownership or control (e.g., deed restrictions) to the extent necessary to ensure the continued protection of human health commensurate with the clean-up levels established by the remedy. If portions of the FEMP property are transferred or sold at any future time, restrictions will be included in the deed, as necessary, and proper notifications will be provided as required by CERCLA.

- Maintenance of the ~~on-site disposal facility will be performed~~ OSDF to ensure its long-term performance and the continued protection of human health and the environment.

- Conduct of an environmental monitoring program during and following remedy implementation to assess the ~~sort~~ short- and long-term effectiveness of remedial actions.

- Provision of an alternate water supply to domestic, agricultural and industrial users relying upon groundwater from the area of the aquifer exhibiting concentrations of contaminants exceeding the ~~final remediation levels~~ FRLs. The alternate water supply will be provided until such time as the area of the aquifer impacting the user is certified to have attained the ~~final remediation levels~~ FRLs.

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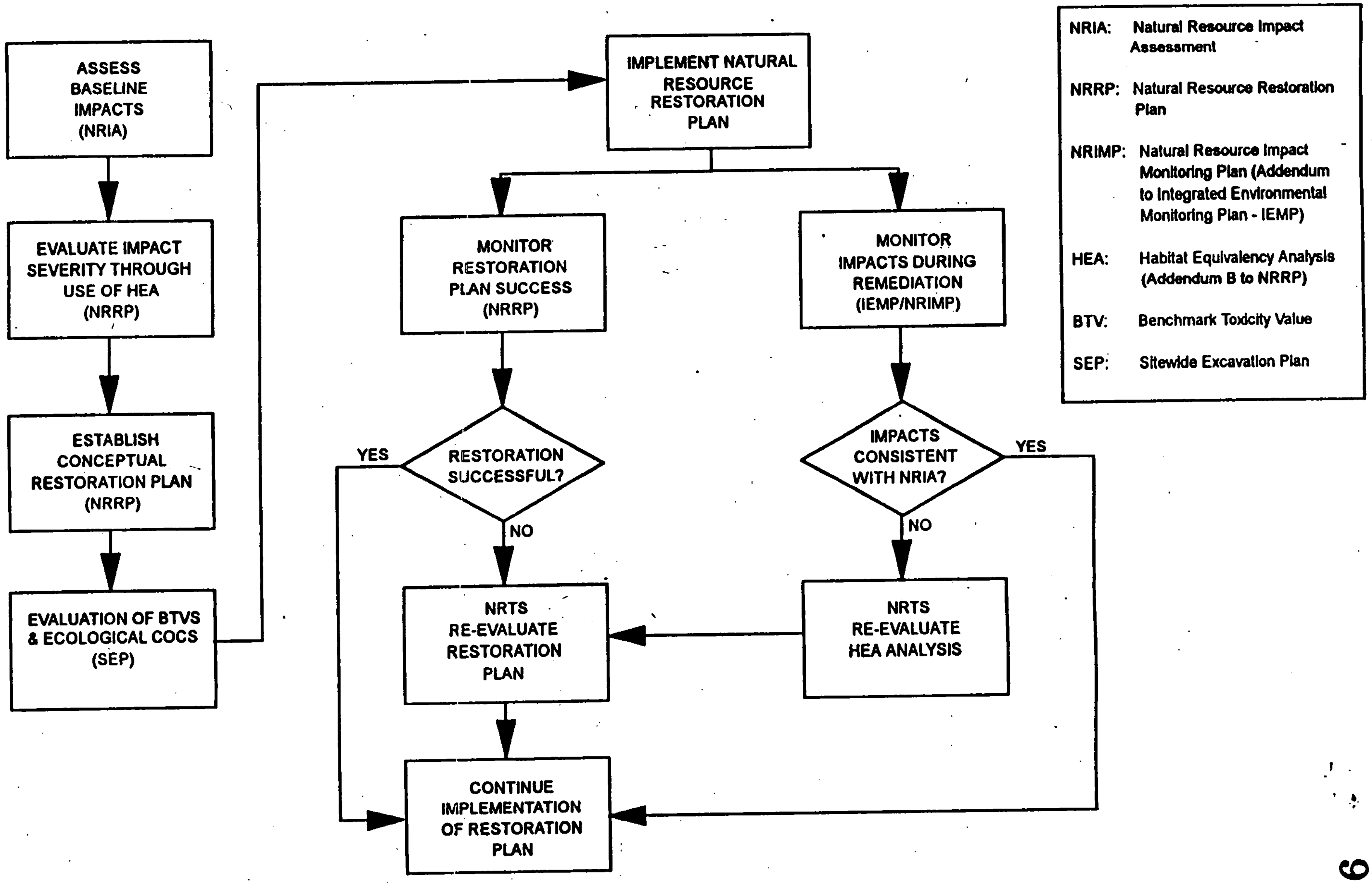
TABLE 3-1: SUMMARY OF IMPACTS AND PROPOSED RESTORATION PROJECTS

Impacted area	Required Restoration (acres)*	Total Proposed Restoration (acres)	Projects Contributing to Restoration†
Paddy's Run Corridor	87.02	86	B & I
Northern Woodlots	74.42	103	D & E
Southern Pines and Waste Units	49.12	49	C & I
Grasslands	282.52	284	A, E, K & L
Waste Storage/Production Area	30.54	31	G & H
Great Miami Aquifer	328.8	329	G, H & J
Great Miami River	7.37	8	E

*From HEA-Addendum B
† Project Letters refer to designations on Figures 3-1 and 3-9

Figure 1-1: NATURAL RESOURCE TRUSTEE DOCUMENTATION PROCESS



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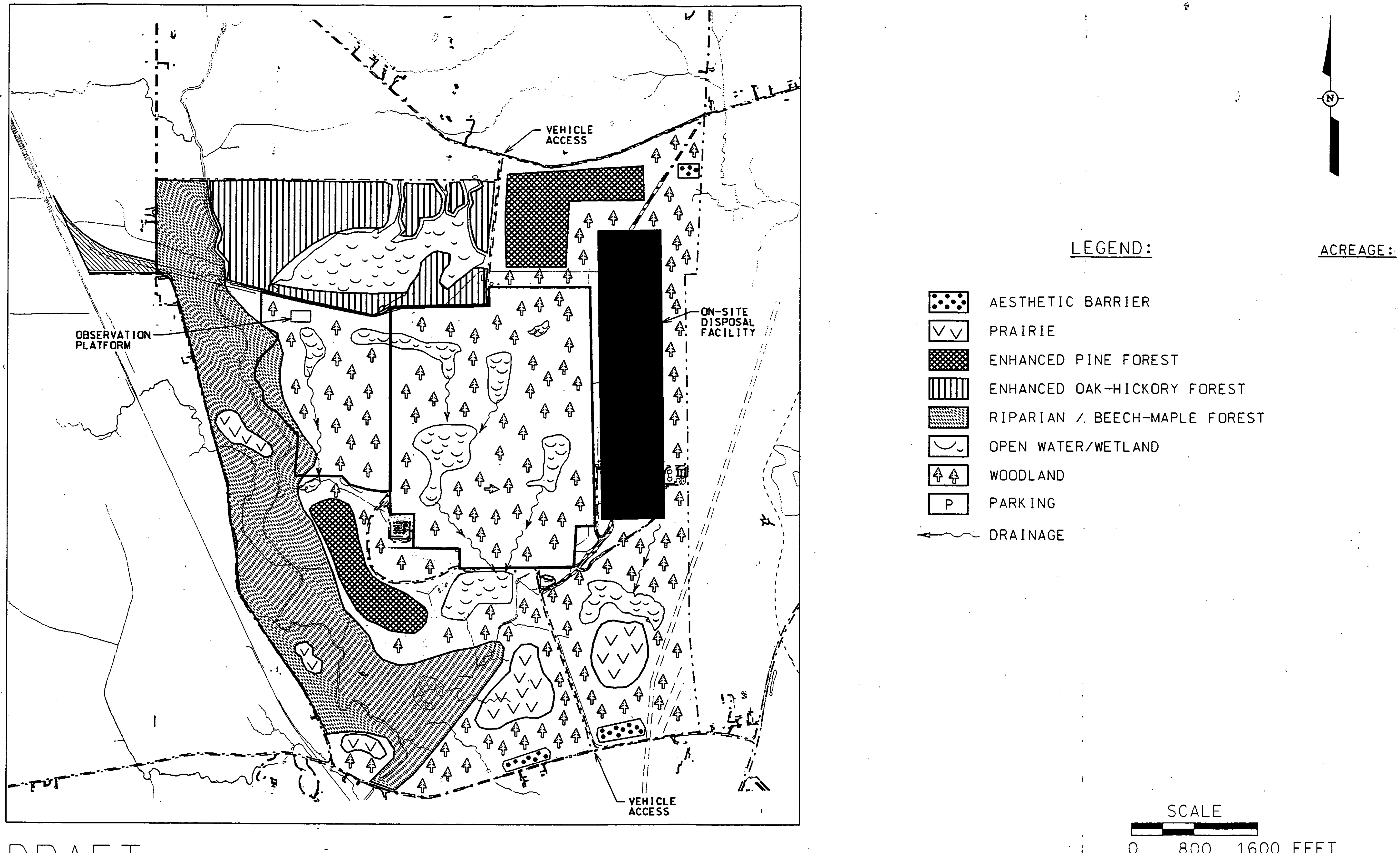

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FIGURE 1-2. CONCEPTUAL FINAL LAND-USE

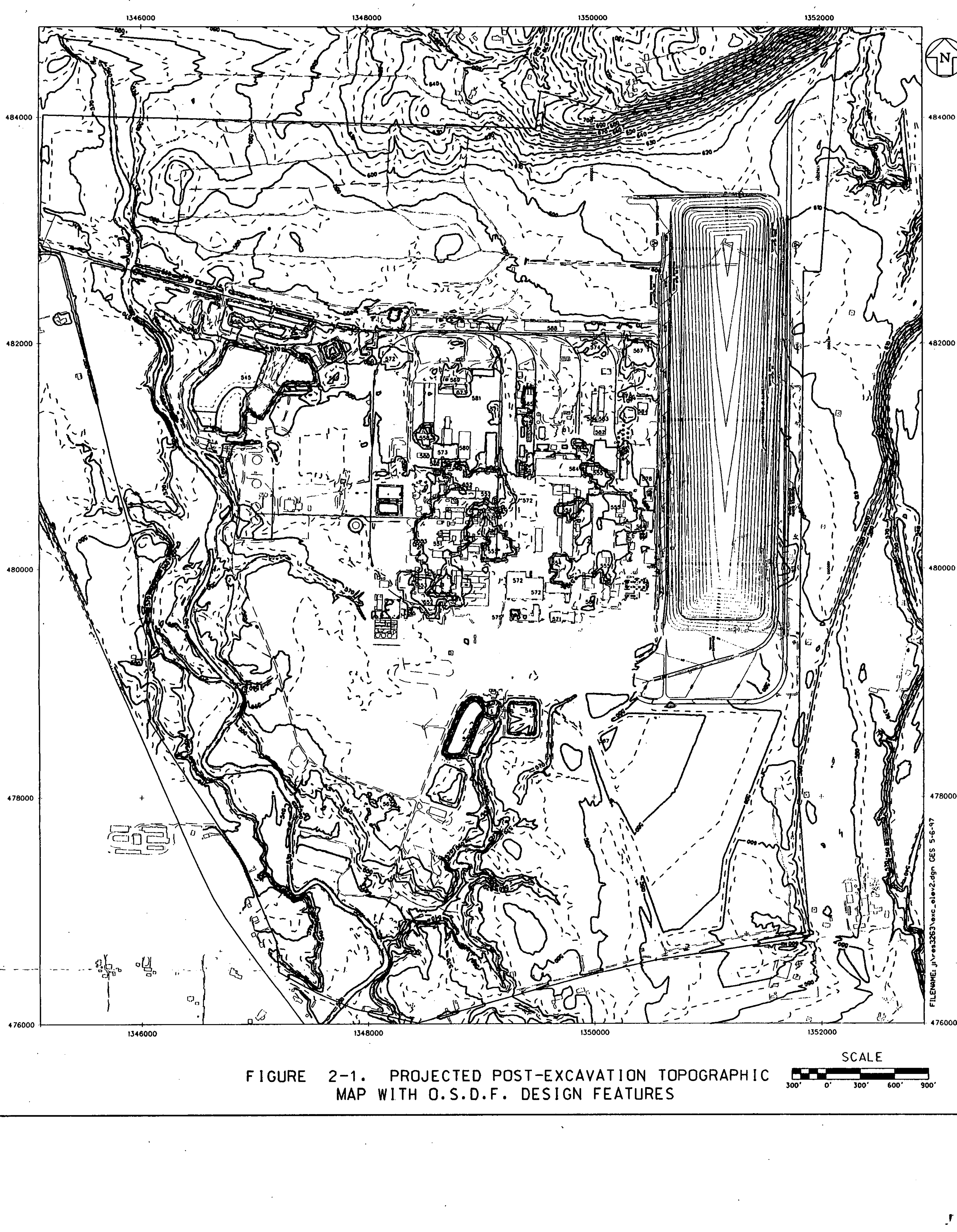

FIGURE 2-1. PROJECTED POST-EXCAVATION TOPOGRAPHIC MAP WITH O.S.D.F. DESIGN FEATURES

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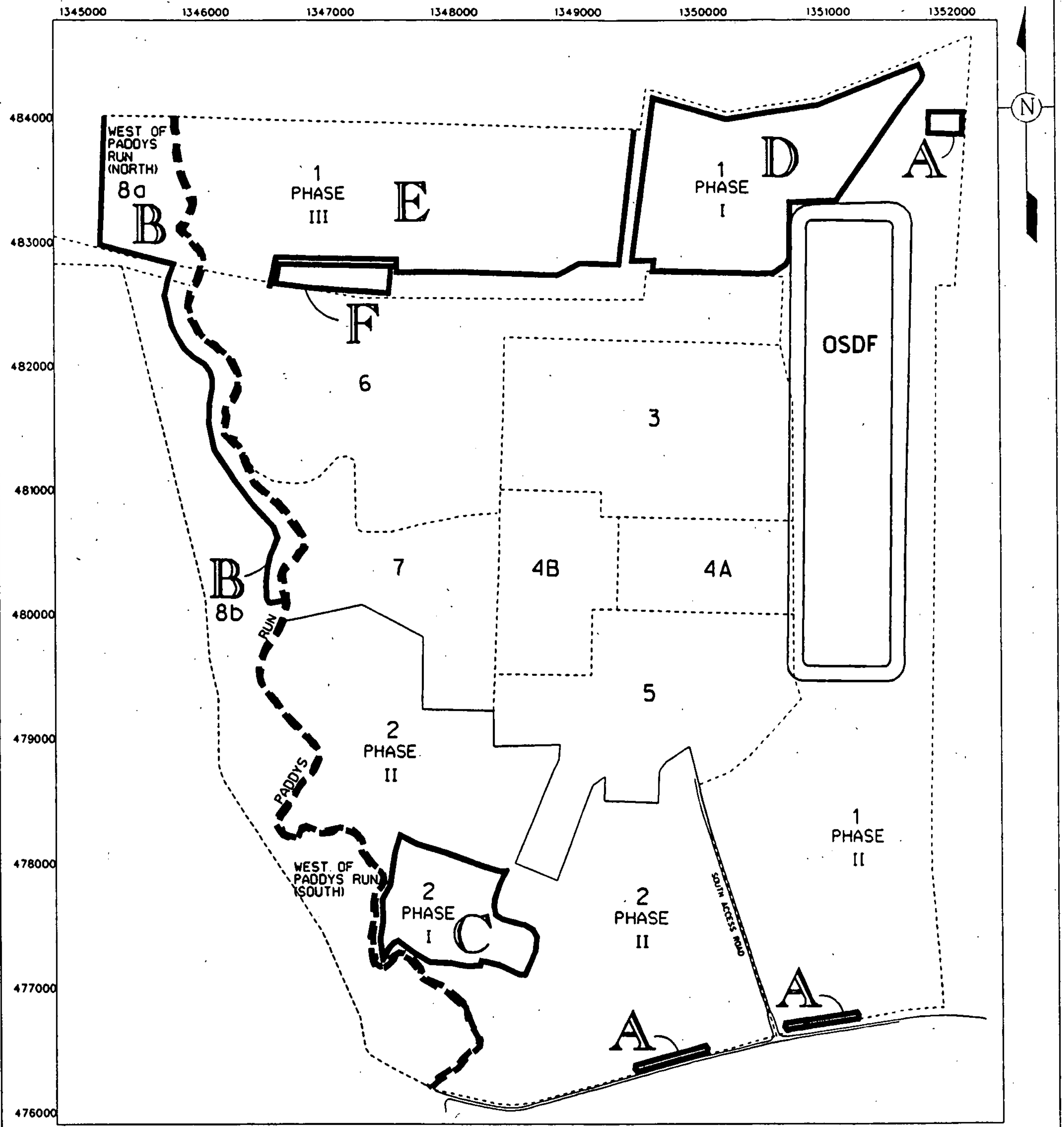
FILE NAME /USR1/RES/RES3256/SKG8.DGN FER OU5 4/7/97 GES STATE PLANAR COORDINATE SYSTEM 1983



LEGEND:

A AESTHETIC BARRIERS/HEDGE ROWS
B DEMONSTRATION FOREST PROJECT WEST OF PADDY'S RUN
C REVEGETATION OF AREA 2, PHASE 1
D ENHANCEMENT OF AREA 1, PHASE 1 WOODLOTS
E ENHANCEMENT AND MANAGEMENT OF AREA 1, PHASE 3 WOODLOTS
F EXPANSION OF NORTHERN FORESTED WETLAND
SOIL EXCAVATION BOUNDARIES
RESTORATION PROJECT AREAS
1 REMEDIATION AREA

SCALE
1200 600 0 1200 FEET

FIGURE 3-1. NEAR TERM RESTORATION PROJECTS

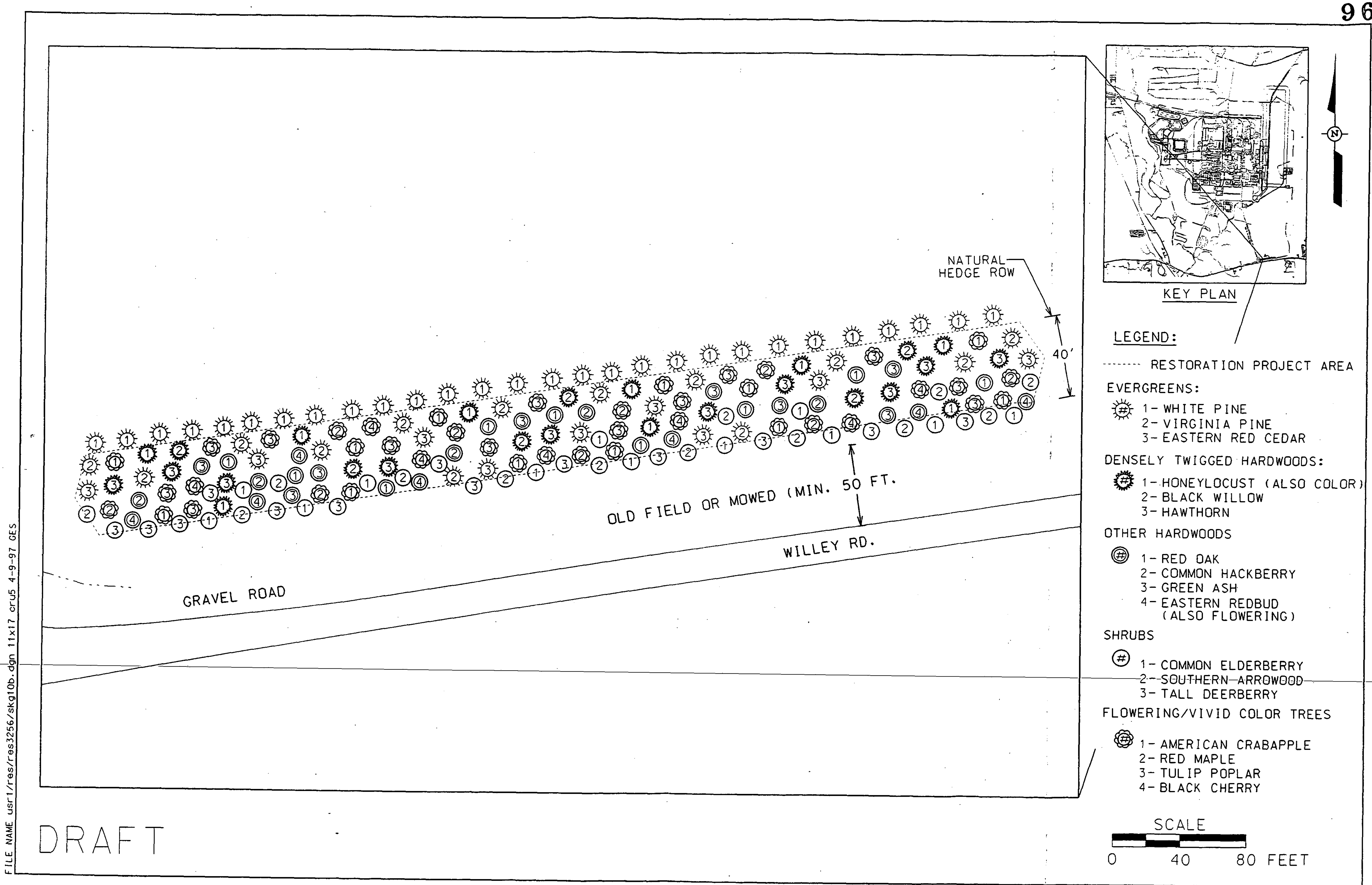


FIGURE 3-2. AESTHETIC BARRIER ALONG WILLEY ROAD

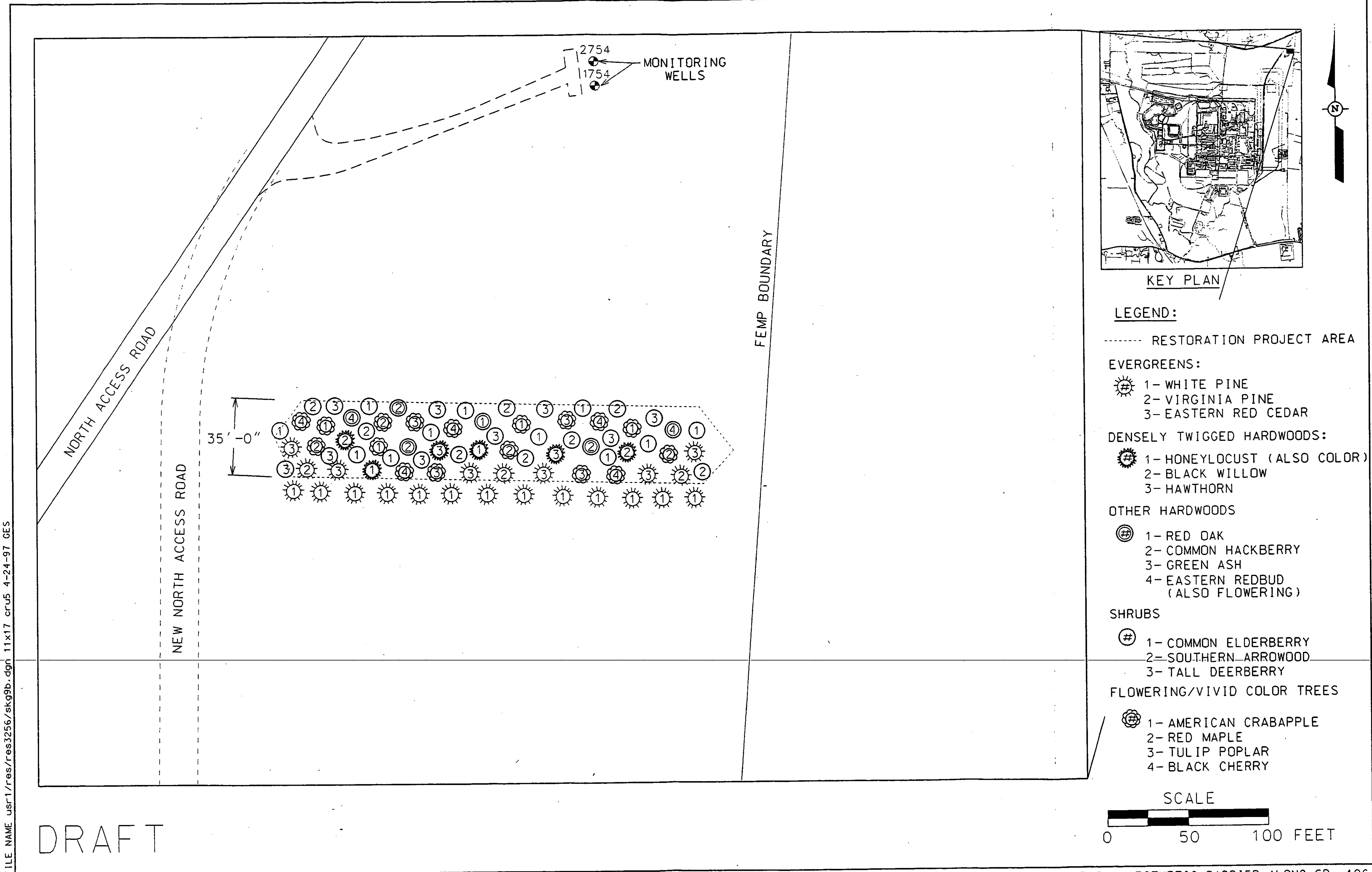
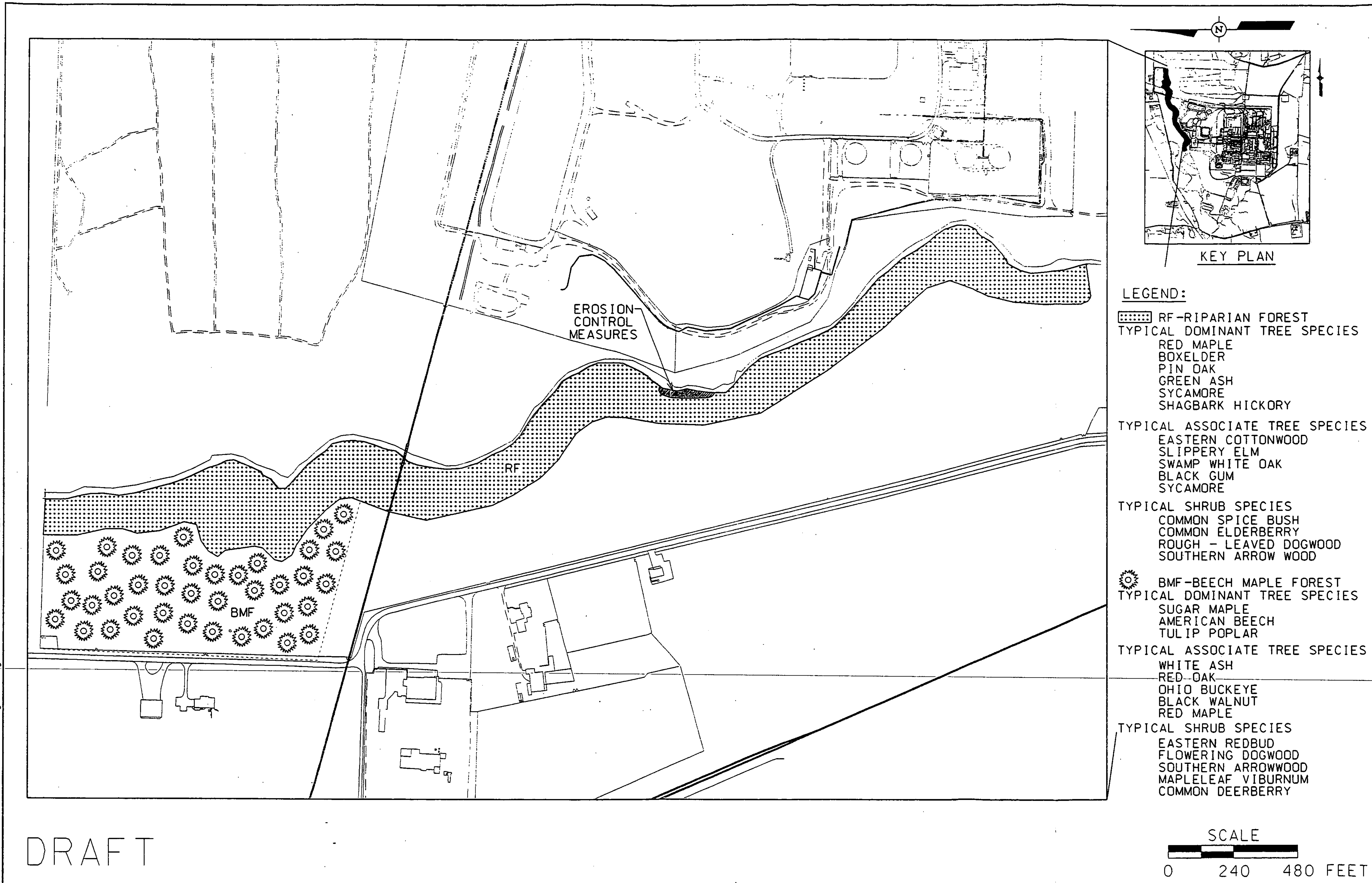


FIGURE 3-3. AESTHETIC BARRIER ALONG SR. 126



FILE NAME usr1/res/res3256/skg13b2.dgn 11x17 cru5 4-22-97 GES

FIGURE 3-4. DEMONSTRATION FOREST PROJECT WEST OF PADDY'S RUN

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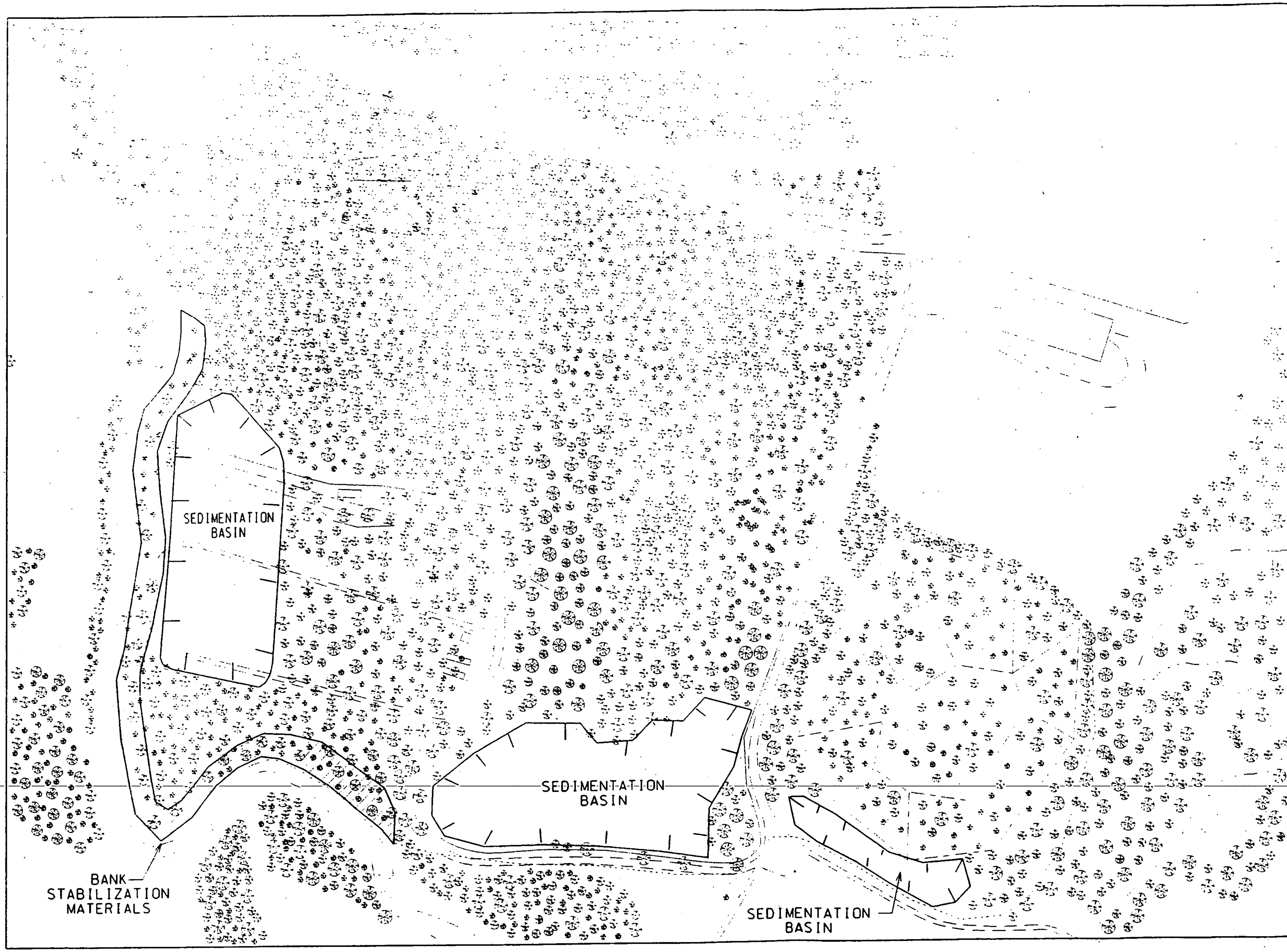
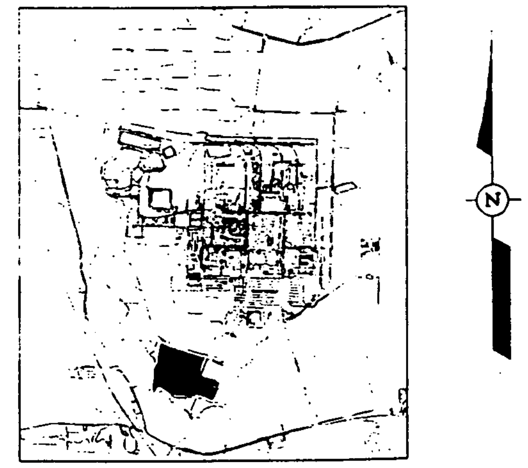




KEY PLAN

LEGEND:

RESTORATION PROJECT AREA

RF-RIPARIAN FOREST

TYPICAL DOMINANT TREE SPECIES
- RED MAPLE
- BOXELDER
- PIN OAK
- GREEN ASH
- AMERICAN SYCAMORE
- AMERICAN BEECH
- BLACK WILLOW

TYPICAL ASSOCIATE TREE SPECIES
- EASTERN COTTONWOOD
- SLIPPERY ELM
- SWAMP WHITE OAK
- BLACK GUM

TYPICAL SHRUB SPECIES
- COMMON SPICE BUSH
- COMMON BUTTONBUSH
- ROUGH - LEAVED DOGWOOD
- SOUTHERN ARROW WOOD
- BURNING BUSH

BANK STABILIZATION MATERIALS

NATIVE TREE & SHRUB CUTTINGS
- BLACK WILLOW
- RIVER BIRCH
- BASKET WILLOW
- RED-OSIER DOGWOOD

BIOLOGS WITH NATIVE TREE AND SHRUB SPECIES PLUGS

LOG DEFLECTORS

SCALE

0 100 200 FEET

DRAFT

FILE NAME usr1/res/res3256/skg14b.dgn 11x17 cru5 4-23-97 GES

FIGURE 3-5. REVEGETATION OF AREA 2, PHASE 1

146

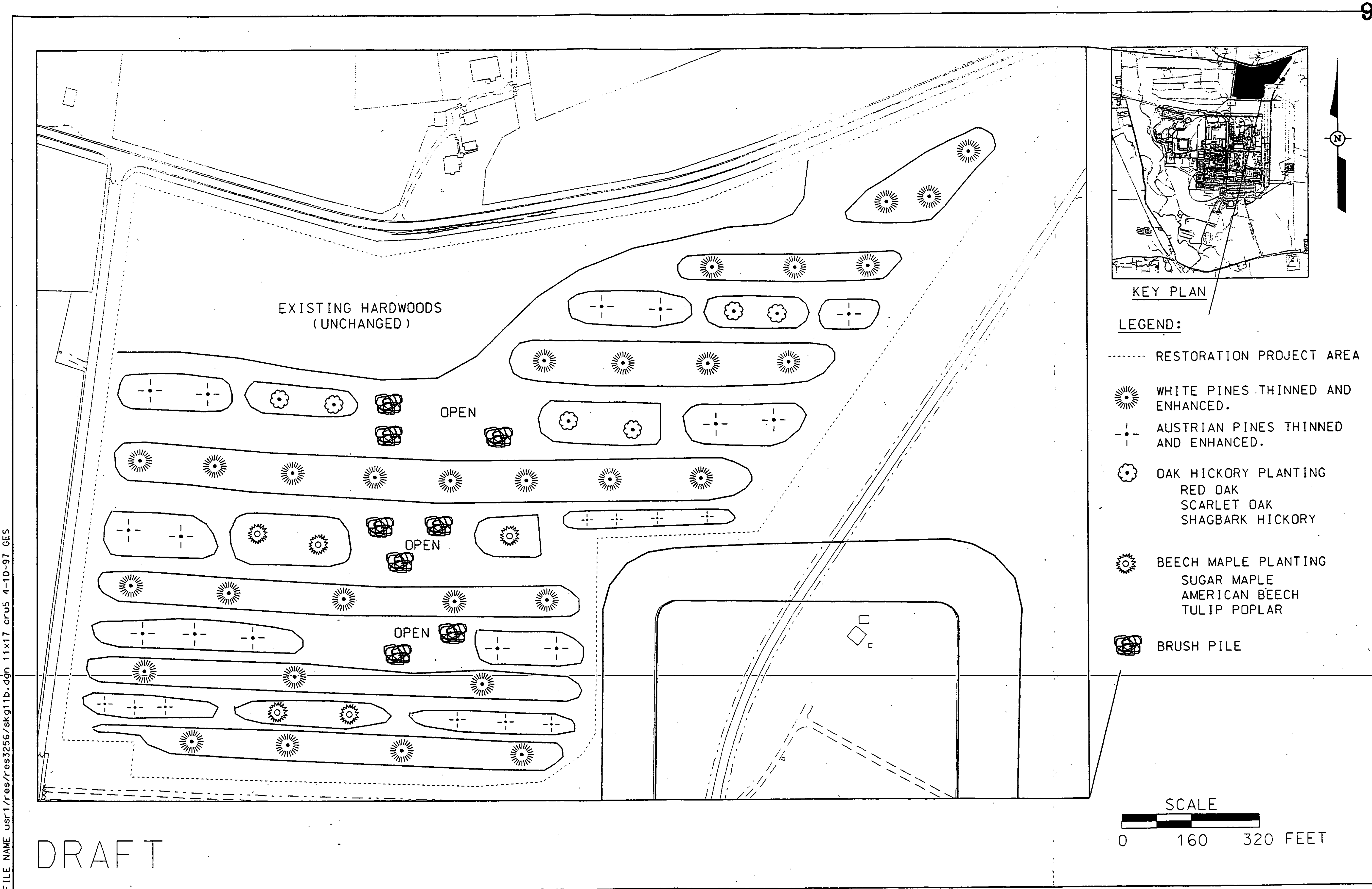


FIGURE 3-6. ENHANCEMENT OF AREA 1, PHASE 1 WOODLOTS

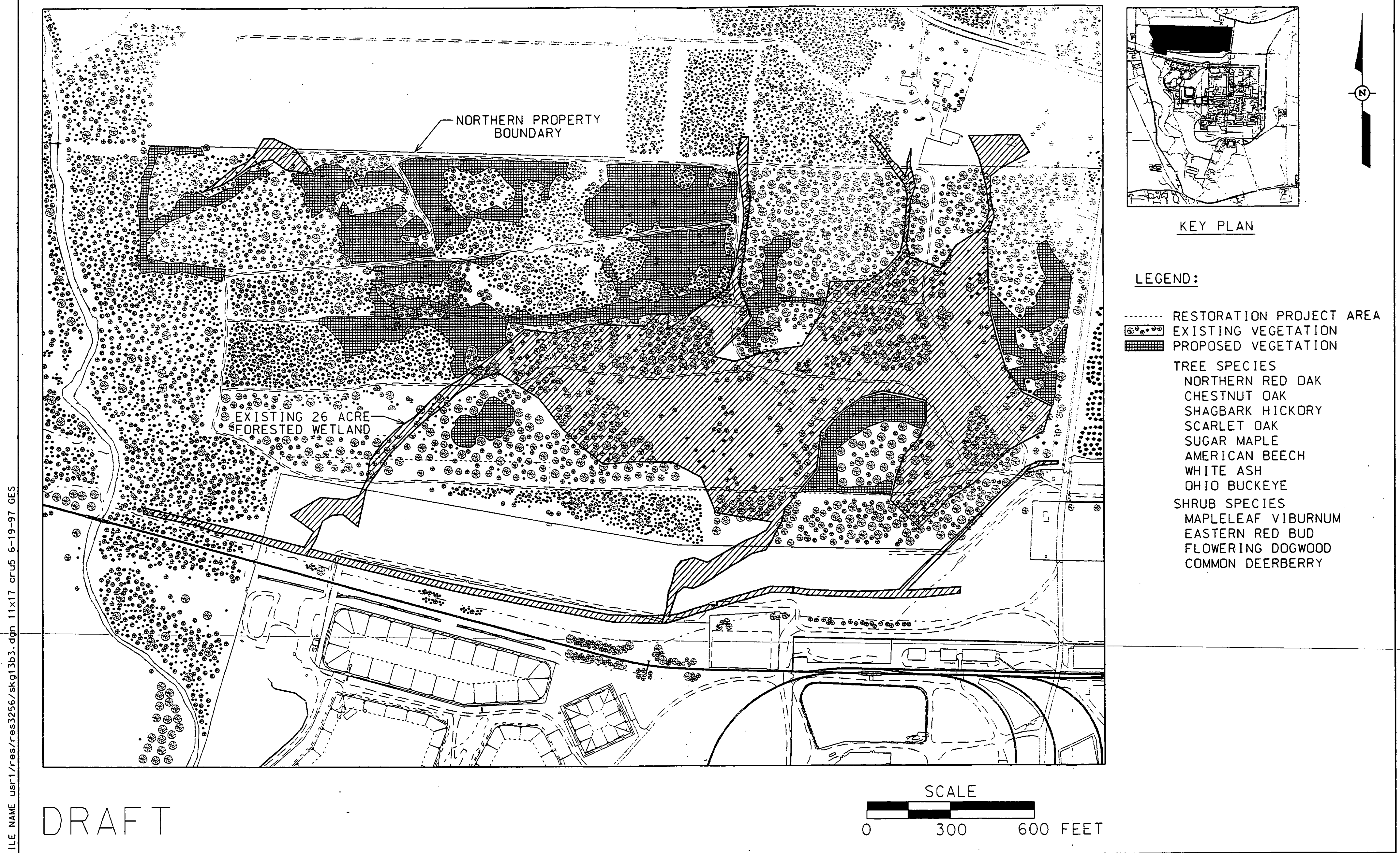


FIGURE 3-7. AREA 1, PHASE 3 WOODLOT

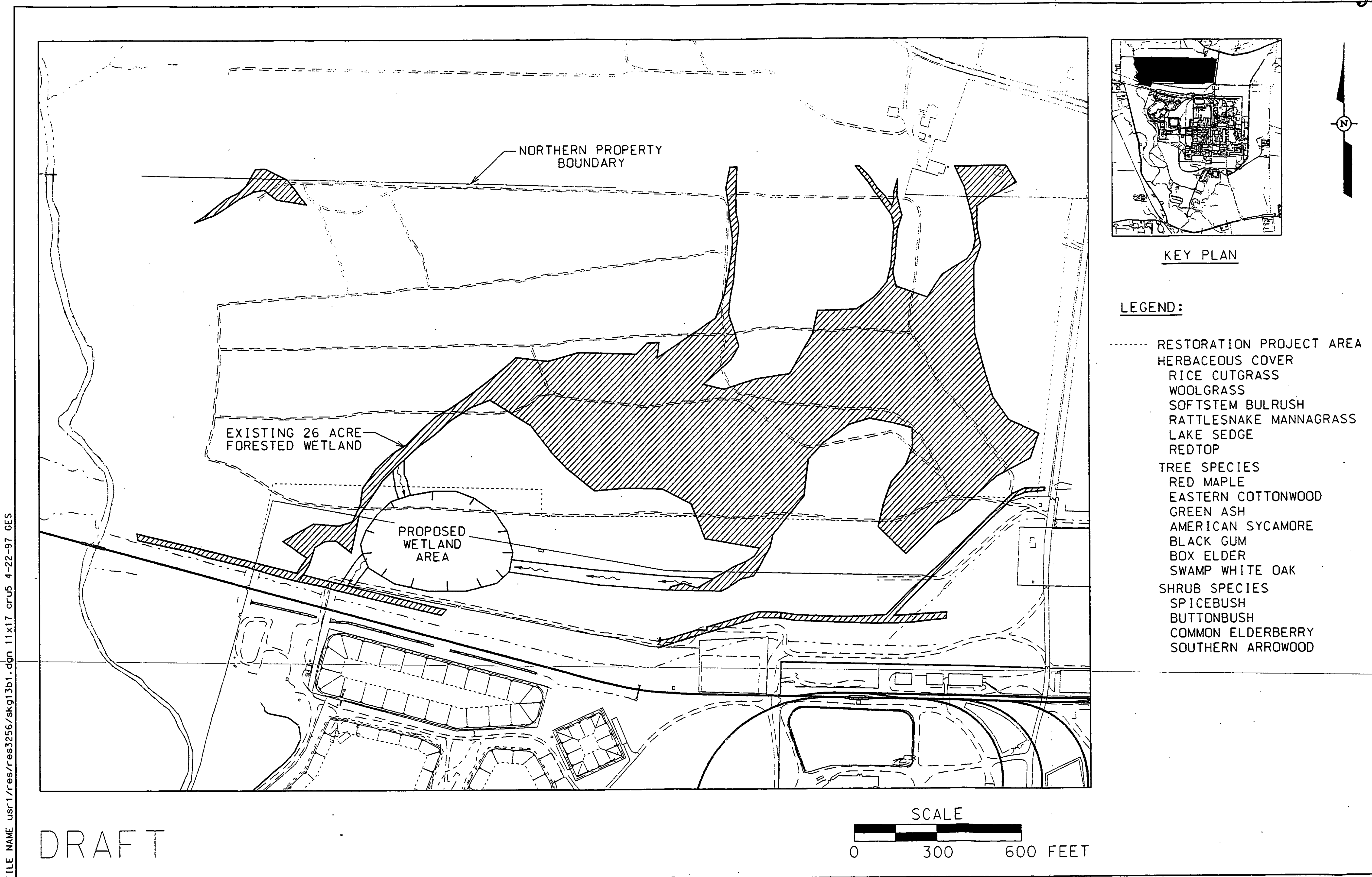
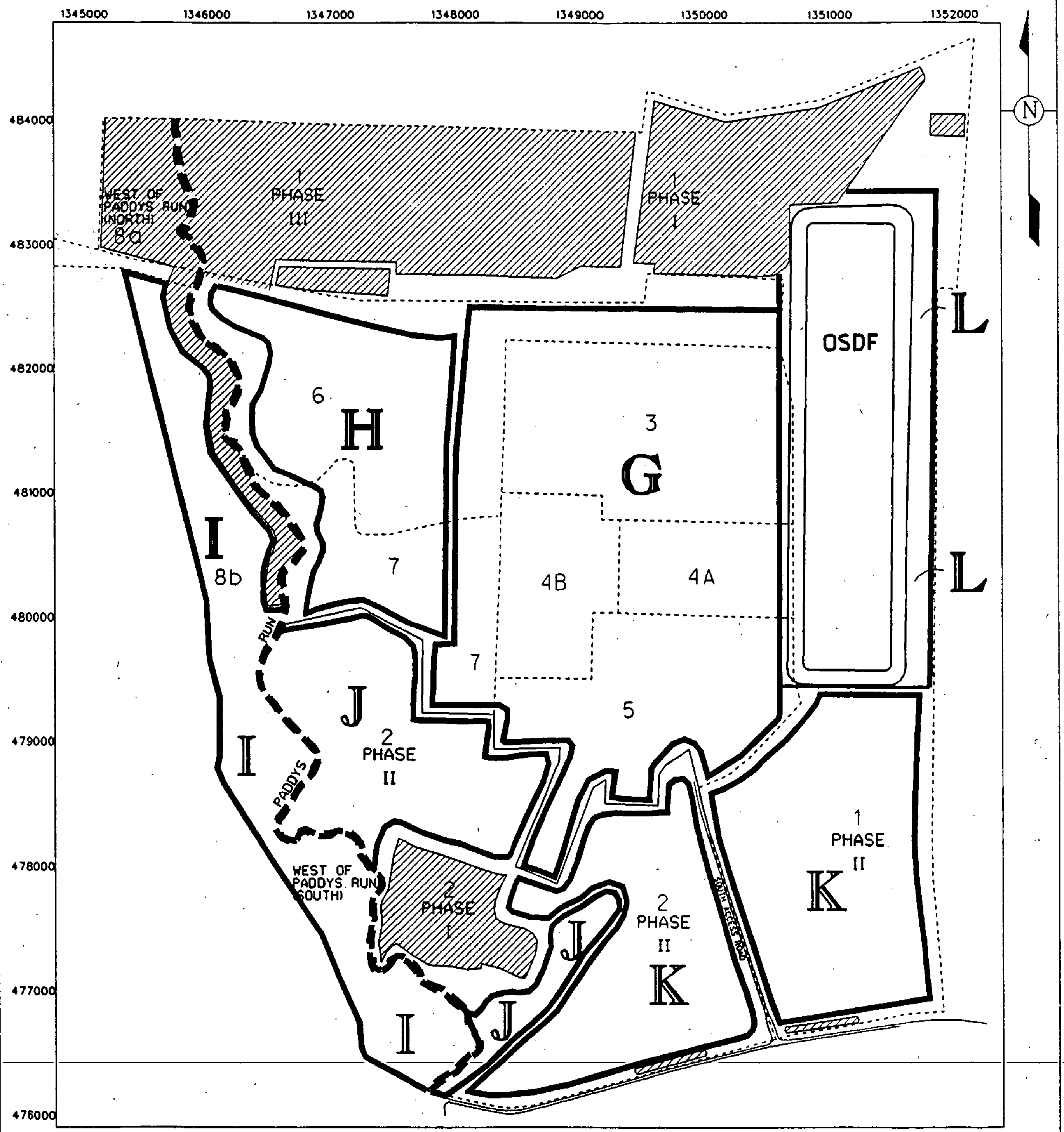


FIGURE 3-8. EXPANSION OF NORTHERN FORESTED WETLAND

FILE NAME /USR1/RES/RES3256/SKG20.DGN FER OU5 4/9/97 GES STATE PLANAR COORDINATE SYSTEM 1983



LEGEND:

G OPENWATER/WETLAND CREATION IN FORMER PRODUCTION AREA
H OPENWATER/WETLAND CREATION IN FORMER WASTE PIT AREA
I PHASE 2 EXPANSION OF PADDYS RUN CORRIDOR WEST
J REESTABLISHMENT OF CORRIDOR EAST OF PADDYS RUN
K BORROW AREA WETLAND CONSTRUCTION/EDGE HABITAT FORMATION
L OSDF AESTHETIC BUFFER
1 REMEDIATION AREA
.... SOIL EXCAVATION BOUNDARIES
RESTORATION PROJECT AREAS
NEAR TERM PROJECT AREAS

SCALE
1200 600 0 1200 FEET

FIGURE 3-9. LONG TERM RESTORATION PROJECTS

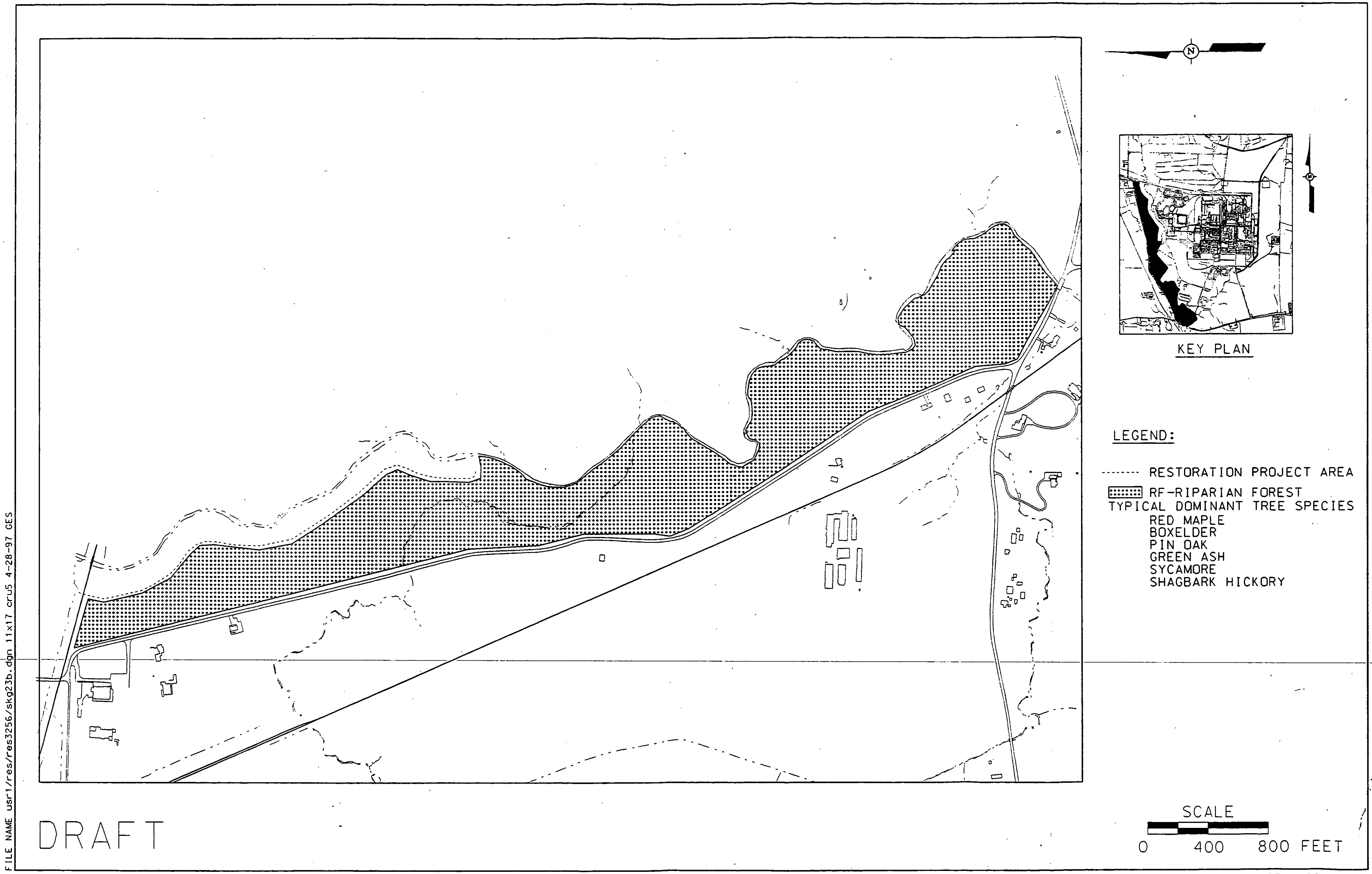


FIGURE 3-10. PHASE 2 EXPANSION OF PADDYS RUN CORRIDOR TO THE WEST

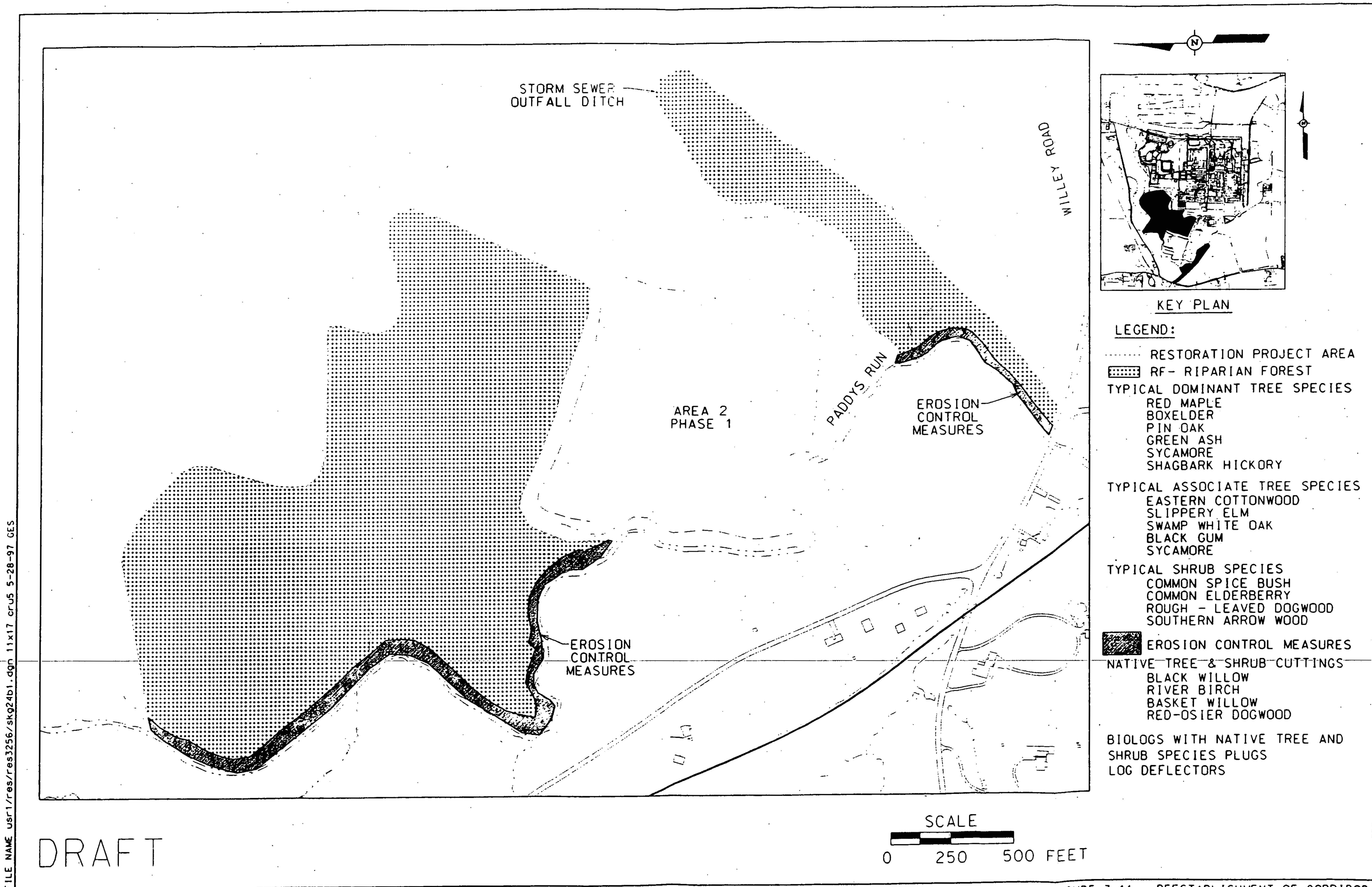
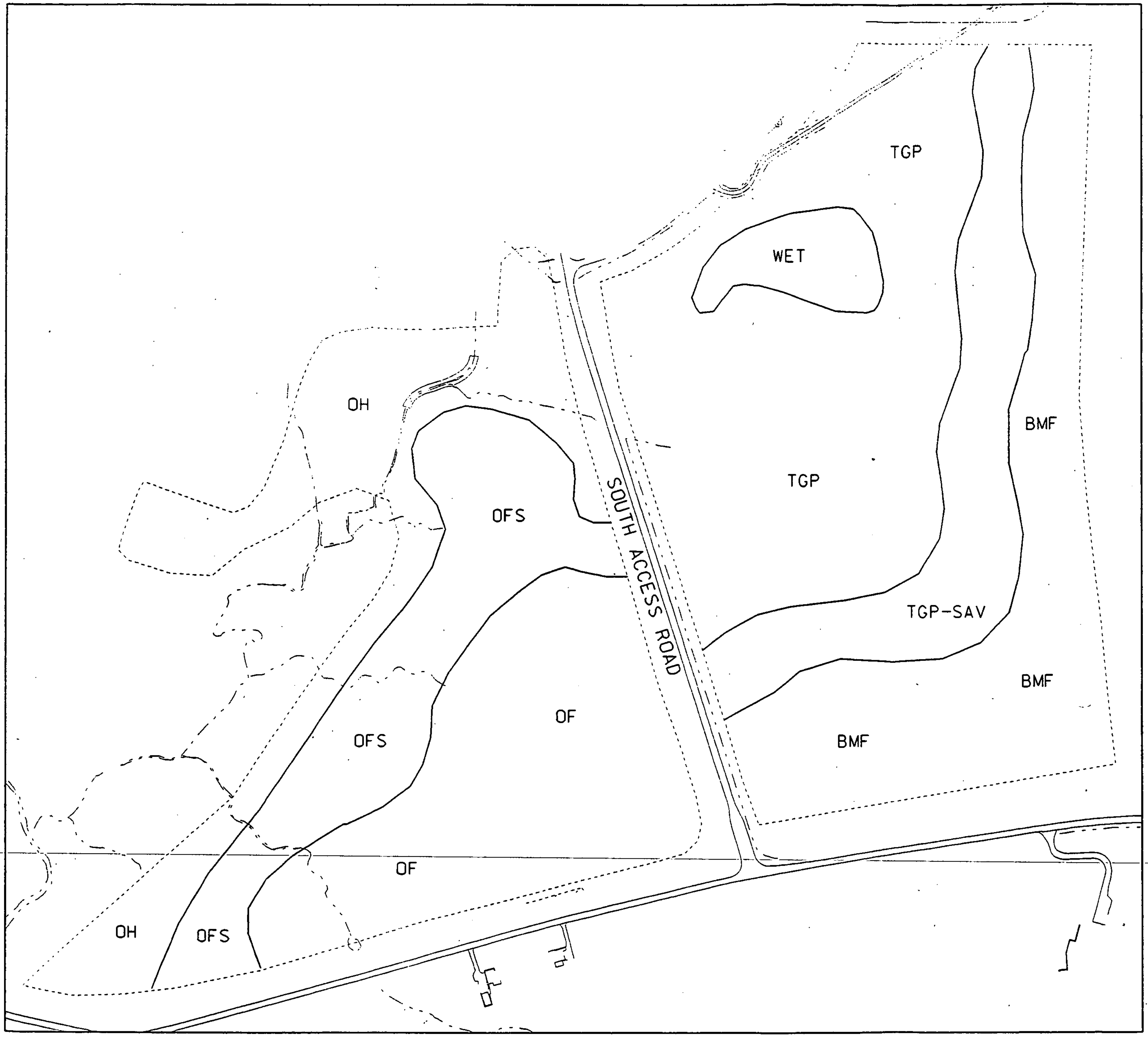
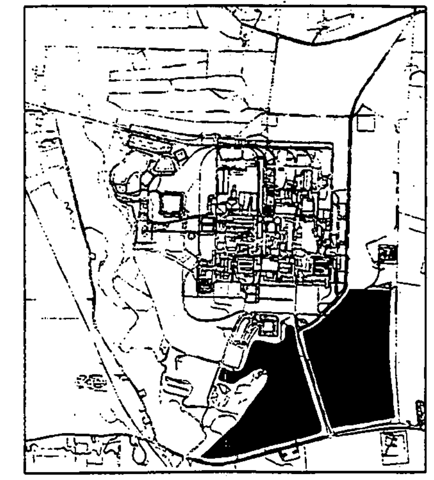
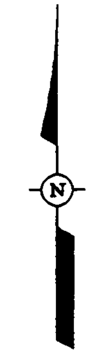


FIGURE 3-11. REESTABLISHMENT OF CORRIDOR EAST OF PADDYS RUN





KEY PLAN



LEGEND:

------- RESTORATION PROJECT AREA

WET WETLAND
- WATER PLANTAIN
- LAKE SEDGE
- SQUARESTEMMED SPIKERUSH
- FRAGRANT WATER LILY
- WATER SMARTWEED
- WIDGEONGRASS
- WILD CELERY

BMF BEECH MAPLE FOREST
- SUGAR MAPLE
- RED MAPLE
- AMERICAN BEECH
- TULIP POPLAR

TGP-SAV TALL GRASS PRAIRIE-SAVANNAH

TREE SPECIES
- RED OAK
- WHITE OAK
- CHESTNUT OAK
- SHAGBARK HICKORY
- SHELLBARK HICKORY
- TULIP POPLAR
- SUGAR MAPLE

PRAIRIE GRASS AND FORB MIX
- INDIAN GRASS
- BIG BLUESTEM
- LITTLE BLUESTEM
- SIDE-OATS GRAMMA
- SWITCHGRASS
- BLACKEYED SUSAN
- PRAIRIE CONEFLOWER
- LANCE-LEAVED COREOPSIS
- PURPLE CONEFLOWER
- PURPLE PRAIRIE CLOVER

LEGEND:

TGP TALL GRASS PRAIRIE
- INDIAN GRASS
- BIG BLUESTEM
- LITTLE BLUESTEM
- SIDE-OATS GRAMMA
- SWITCHGRASS
- BLACKEYED SUSAN
- PRAIRIE CONEFLOWER
- LANCE-LEAVED COREOPSIS
- PURPLE CONEFLOWER
- PURPLE PRAIRIE CLOVER

OH OAK-HICKORY
- RED OAK, SCARLET OAK,
- SHAGBARK HICKORY

OFS OLD FIELD SHRUB
- BLACK CHERRY
- BLACK LOCUST
- STAGHORN SUMAC
- COCKSPUR HAWTHORN
- PRAIRIE ROSE
- DWARF CHINKAPIN OAK

OF OLD FIELD

HERBACEOUS
- REED CANARYGRASS
- REDTOP
- BIRDSFOOT TREFOIL

TREES AND SHRUBS
- BLACK CHERRY
- BLACK LOCUST
- STAGHORN SUMAC
- COCKSPUR HAWTHORN
- PRAIRIE ROSE
- DWARF CHINKAPIN OAK

SCALE

DRAFT

FILE NAME usr1/res/res3256/skg25b1.dgn 11x17 cru5 5-29-97 GES

FIGURE 3-12. BORROW AREA WETLAND CONSTRUCTION /EDGE HABITAT FORMATION

ADDENDUM A

SUMMARY OF THE ECOLOGICAL CONSTITUENT OF CONCERN REVIEW

SUMMARY OF THE ECOLOGICAL CONSTITUENT OF CONCERN REVIEW

DOE must ensure that ecological receptors are not adversely impacted by residual contamination that may remain after remediation is complete. One early step towards this goal was taken with the publication of the Site-wide Ecological Risk Assessment (SERA), which was conducted as part of the Operable Unit 5 (OU5) Remedial Investigation.

The SERA considered both radiological and non-radiological risks to ecological receptors within distinct study areas at the FEMP. For radiological risks, site concentrations within each study area were used to calculate the radiological dose rates accrued by individuals of various representative species. All of these doses fell well below the target level dose of 36.5 rad/year, as established by the International Atomic Energy Agency.

For non-radiological risks, potential constituents of ecological concern (COECs) were determined for each study area by comparing existing data to literature-derived benchmark toxicity values (BTVs). The results of this effort showed that 17 soil COECs were present in one or more study areas across the FEMP. Several other COECs were identified for surface water, sediment in Paddys Run and the Great Miami River.

BTVs are not ecological cleanup levels, but rather threshold values that are protective of ecological receptors. An exceedance of a BTV indicates that further investigation may be needed, and does not necessarily indicate ecological impact. Because of this, further investigation of information developed in the SERA was to have been deferred until after all human health-driven remediation has been completed. However, as negotiations with the FEMP Natural Resource Trustees progressed, it became clear that in order to resolve all Trustee concerns, ecological impacts must be considered before remedial activities have been completed. Therefore, a second ecological risk screening was conducted, which is found in Appendix C of the Sitewide Excavation Plan (SEP).

METHODS

A list of all potential COECs was compiled from the SERA BTV list and the OU5 final remediation level (FRL) list. If a SERA BTV was not available, then an alternate BTV was obtained from one of several existing databases. After reducing the potential COEC list to constituents with a BTV that is a lower concentration than its corresponding FRL, sitewide existing soil concentrations were extracted from the Sitewide Environmental Database (SED) and compared to the SERA or proposed BTV for all remaining constituents. If sitewide maximum concentrations exceeded the screening value, the constituent was retained for remnant data evaluation. Remnant (i.e. post excavation) soil concentrations were estimated by considering only soil samples that fell outside of the uranium footprint of excavation. This remnant data set was then compared to the SERA or proposed BTV for each constituent. Samples in the remnant data set that exceeded a BTV were examined to see if they were located within an area that would be excavated because they contain constituents other than uranium in concentrations exceeding their respective FRLs. In other words, the remnant data set often included samples that will be excavated, even though they may fall outside the uranium footprint of excavation.

The SERA did not investigate any source areas associated with other Operable Units, such as the Production Area (OU3), Waste Storage Area (OU1), etc., because it was assumed that these areas would be fully remediated. This was the only consideration given with respect to planned remedial activities. Therefore, now that remedial activities are better defined, further investigation into the SERA findings was necessary. To address these findings, a re-evaluation was conducted for the 16 soil COECs indicated as a concern in the SERA (while the SERA found 17 COECs, the uranium FRL is lower than its BTV, so it was not evaluated any further). The factors considered in the re-evaluation are as follows. Updated representative concentrations were determined for each SERA COEC in each study area. This was conducted to account for the most recent data set and to fully consider nondetects in the statistical determination of representative concentrations. Background values were also compared. In several instances, the SERA BTV was at a concentration lower than site background values. The bioavailability of given constituents in soil was also qualitatively reviewed. Receptor values were then considered for constituents in each study area. This effort considered the end use of the given area and the subsequent ecological receptors that would be expected. Finally, localization and extent of excavation were evaluated for each potential COEC in an attempt to determine patterns of contamination and whether or not the constituents would be expected in post-excavation soils. These last two considerations were augmented by the remnant data review described earlier.

It is anticipated that COECs for surface water and sediment will be addressed through the site-wide remediation of soil and other source material. The Integrated Environmental Monitoring Plan (IEMP) will be used to verify protection of aquatic receptors for the duration of remedial activities. To evaluate the potential for BTV exceedances in restored surface water habitats at the FEMP, modeling was conducted using the remnant data set. Constituents that are anticipated to remain in FEMP soils after remediation is complete were input into the OU5 Surface Water Flow and Infiltration Model (SWF&IM). This model, developed for the OU5 RI/FS, is a combination of FEMP-specific hydrological input parameters and several hydraulic and transport models that is used to simulate transport of contaminants from surface soil to surface water. For each designated sub-basin at the FEMP, maximum remnant concentrations were used. When remnant concentrations were not present, background values were used, if available.

RESULTS

The results of the post-excavation COEC evaluation concluded that only antimony, cadmium, and silver are likely to be present in sufficient amounts in post-excavation soils. These COECs are anticipated to be limited to the Solid Waste Landfill, Active Flyash Pile, Sewage Treatment Plant, K-65 Silos, and the Production Area in the vicinity of the Boiler Plant and Building 12. Also, the concentrations are anticipated to be only slightly above their corresponding BTVs. Molybdenum may be an additional concern around the Active Flyash Pile.

The SERA re-evaluation found that the only potential concern for ecological receptors would be lead in the vicinity of the trap range. This concern will be addressed through current FRL-driven excavation, as evidenced by the results of the remnant data evaluation.

The results of the surface water and sediment modeling indicated that no post-excavation surface water or sediment concentrations are expected to be an ecological concern. Manganese did show BTV exceedances for both surface water and sediment. However, these exceedances were driven by the background concentration for manganese, which was plugged in to most sub-basins as the representative concentration.

RECOMMENDATIONS

Based on this evaluation, there appears to be limited potential for post-excavation exceedances of BTVs. In other words, remediation to meet FRLs at the FEMP will essentially address areas of potential ecological risk at the site. Therefore, for the three COECs retained as a result of the evaluation (and molybdenum around the Active Flyash Pile), it is recommended that each be added to the sampling parameters for each of the certification units in which the remnant data identified a potential exceedance. The existence of post-excavation, above-BTV soil concentration could trigger further evaluation by the FEMP Natural Resource Trustees and be factored into the natural resource restoration planning process as appropriate. However, certification of an area will not be dependent on whether all BTVs are met. The restoration plans outlined in the NRRP will not be jeopardized by isolated above-BTV concentrations in remediated areas of the site. Steps can be taken as part of restoration (e.g., backfilling, installing liners) to minimize the exposure of ecological receptors to above-BTV concentrations, if determined appropriate by the FEMP Natural Resource Trustees.

ADDENDUM B

HABITAT EQUIVALENCY ANALYSIS

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ADDENDUM B - HABITAT EQUIVALENCY ANALYSIS

1.0 Introduction

The goal of negotiations between the Fernald Natural Resource Trustees (NRTs) is to resolve the Department of Energy's liability for natural resource injuries, including the settlement of the State of Ohio's 1986 claim against DOE, by implementing an on-property natural resource restoration plan. The NRTs have tentatively agreed to pursue resolution of their concerns without conducting a formal Natural Resource Damage Assessment (NRDA). Therefore, any restoration plan for the Fernald Site must be justified through a process that meets ~~at least~~ the minimum substantive aspects of the NRDA process and CERCLA.

A key aspect of the natural resource trusteeship process is ensuring that restoration adequately compensates for injuries. Within an NRDA, this is accomplished by converting injuries to dollar damages, which are then spent to replace, restore, or acquire natural resources equivalent to those injured. The NRTs have agreed to pursue an alternate method to ensure that the level of natural resource restoration at the Fernald site is commensurate with the impacts that have occurred.

To accomplish this, the NRTs have tentatively agreed to pursue the use of the Habitat Equivalency Analysis (HEA) process to bridge the gap between the Natural Resource Impact Assessment (NRIA) and the Natural Resource Restoration Plan (NRRP). The NRIA provides a baseline of past and anticipated future impacts that have occurred at the Fernald site. Based on those impacts, the NRTs have formulated the appropriate level of restoration, as defined by the evaluation in this addendum, to compensate for the agreed-upon impacts and to address all stakeholder concerns.

2.0 Habitat Equivalency Methodology

The HEA process is one of the methods available to determine the appropriate compensation for the loss of natural resources. By using the HEA methodology, the NRTs have the flexibility to calculate the acreage of a habitat replacement project necessary to compensate for the loss of services provided by a natural resource. An example of a service loss would be the contamination of groundwater to the extent it cannot be used for drinking water or the contamination or destruction of a wetland system to the point it no longer provides the beneficial functions of a healthy wetland. Replacement (i.e., compensatory) projects proposed would be in addition to any "primary" restoration project that may be required by some other regulatory driver (e.g., wetland mitigation required by the Clean Water Act).

Compensatory projects proposed would be designed to restore the resource to baseline conditions (to the extent possible) which would serve to make the resource whole.

Although there is a distinction made between primary and compensatory restoration projects for the purposes of compliance with regulatory requirements and implementation of the HEA process, the two may involve the same restoration activities (e.g., revegetation, creation of wetlands). However, it is important to note that there can be distinct and different projects implemented to meeting primary and compensatory restoration requirements. At the Fernald site, the intent is to propose and implement a comprehensive restoration plan (as outlined conceptually in the NRRP) to meet both primary and compensatory restoration requirements. However, for purposes of the HEA process, the distinction between primary and compensatory restoration is necessary to ensure that a project proposed to meet a regulatory requirement are not also counted as compensation for a natural resource injuries.

The ultimate goal of the HEA process is to calculate compensation based on some agreed upon level of injury for each natural resource area. This calculation will serve to demonstrate the increase in services provided by the replacement project will be of equivalent value to the public as the value of services lost due to the injury. Because detailed quantitative data is generally lacking to value the exact loss of services from a past (or future) injury, HEA calculates an equivalency between the quantity of services lost due to the injury and the quantity of services provided by the replacement projects over time.

The NRTs will negotiate the amount of yearly service loss for a particular area based upon the amount of injury that has occurred. In the case of the Fernald Site, the injuries or impacts have been outlined by distinct study areas in the NRIA. Therefore, the NRTs will negotiate an appropriate level of service loss for each particular study area outlined in the NRIA. In addition, the NRTs will negotiate the appropriate level of service gain provided by the restoration projects. Based on the negotiated level of service loss and gain, the HEA methodology will calculate the amount of compensatory restoration required (in acres) to offset of natural resource impacts or injuries. The compensatory restoration acres are calculated as explained below.

2.1 Calculations

Two worksheets were developed to calculate HEA acreages for each NRIA area. These worksheets provided for each area will include the columns described below. The first (left side) worksheet calculates the interim loss in services by determining *effective acre-years* lost. This is accomplished by taking the negotiated service level (column 3) for each year (column 1) and subtracting from 100% to get an annual percent service loss (column 4). In column 5, the average annual percent service loss is calculated by averaging the given year and the following year service losses. For instance, if year 1 had a service loss of 20% and year 2 had a service loss of 40%, the average annual percent service loss would be 30%. A discount factor of 3% is then applied in column 6 using the following equation: $1/(1+0.03)^{\text{given year - 1997}}$. This discount factor is then multiplied by the average annual percent service loss to obtain an average service loss per acre (column 7). This value is then multiplied by the total area acreage (found in the "Related Information" section at the bottom right of the various worksheets) to get an effective acres lost value for each year of impact. These annual acreages are then summed at the bottom of the worksheet to obtain a total discounted effective acre-years lost.

Service increases are then calculated. The first three columns of the service increase worksheet have similar values with respect to the percent service levels for the given years. Rather than calculating loss, however, an average percent service level change is calculated for each year. This is accomplished by again averaging the percent service change in a given year with the following year (column 4). This value is again discounted using the same discount factor equation as described above (column 5) and multiplying it by the average annual percent change to determine an effective acre-years per acre gain (column 6). These annual values are summed at the bottom of the worksheet to obtain a total gain in discounted effective acre-years per acre restored.

To determine the amount of compensatory restoration that is required, the total interim loss acre years are divided by the total gains in effective acre-year per restoration acre in order to obtain the total amount of compensatory acreage needed. These calculations are shown below the service increases tables on each worksheet. The compensatory restoration acreage is then added to the primary restoration acreage to determine the total restoration acreage required.

2.2 Conditions and Assumptions for Use

In order to use HEA in the determination of compensatory restoration requirements, certain conditions must be met. General guidance lists four conditions of use for conducting HEA calculations. Each of these conditions and their applicability to the FEMP are discussed below. The use of HEA to calculate groundwater compensation will be discussed separately.

2.2.1 Values of Lost Services are Comparable to Replacement Services

Primary and compensatory restoration plans must provide services comparable to the services lost due to injuries. Restoration alternatives at the FEMP are centered around expansion, enhancement, and restoration of site habitats that have been or will be impacted due to CERCLA releases and/or remedial activities. Most of the habitats proposed in the Natural Resource Restoration Plan are habitats that have been or are presently located on FEMP property, which will provide the same services with respect to wildlife habitat, nutrient cycling, etc. Therefore, replacement services will be comparable to lost services. It should be noted that in some instances lower quality habitats will be replaced with higher quality habitats. For instance, many of the introduced grasslands located on property will be converted into deciduous woodlots. In these cases, an adjustment factor is used in the HEA calculations as an increase in service levels over 100%.

2.2.2 Injuries Primarily Affect Ecological Services

The use of HEA is recommended only if on-property human uses are limited and off-property human uses are difficult to quantify. This condition is met at the FEMP, where human access to the site is restricted and service losses are primarily the result of ecological impacts due to habitat loss.

2.2.3 Replacement of Habitat Services is Feasible

Service losses due to habitat impacts can be replaced with the expansion, enhancement, and restoration of representative habitats. These actions consist of standard erosion controls, grading, and revegetation, which will be detailed in the NRRP. The land for these actions is available on property, with the final land use scenario being an undeveloped park. Therefore, natural resource restoration at the FEMP will replace lost habitat services. The NRRP is conceptual at this time. As design progresses, specific restoration plans may be altered for technical reasons. Any plan revisions must still meet the restoration goals identified through the HEA process and through negotiations with the FEMP NRTs.

2.2.4 Nature of Injuries and Replacement Projects are Sufficiently Understood to Estimate HEA Parameters

Through the RI/FS process, volumes of information have been collected with respect to natural resource injuries and associated service losses at the FEMP. Likewise, remedial design efforts provide sufficient information to estimate service gains through restoration projects. Certain service loss and gain percentage calculations require the use of assumptions derived from existing information, current remedial design schedules, and the science of ecology. These assumptions are spelled out in the following section.

The conditions for the use of HEA are met at the FEMP for all impacts due to soil remediation. When considering groundwater, the calculation of replacement services for impacts to the Great Miami Aquifer do not meet the conditions of HEA. However, the FEMP NRTs have collectively decided to pursue a resolution of groundwater impacts through habitat restoration calculated by a modified HEA exercise. This modification involved the use of terrestrial habitat restoration to compensate for lost services to groundwater.

The assumptions used to apply HEA at the FEMP can be divided into three major categories: general assumptions; assumptions associated with service losses; and assumptions associated with service gains. in addition, specific assumptions have been made for each of the areas evaluated in separate HEA calculations. These assumptions are described within the corresponding description of the area-specific HEA calculations.

2.3 General Assumptions

The first general assumption used in the FEMP HEA calculations is that the future impact acreage identified in the NRIA is equivalent to the primary restoration project for the area in question. In other words, if no natural resource injury compensation were required, DOE would mitigate the loss of impacted habitats at a one to one ratio. This is the case for all areas evaluated at the FEMP except for the Production Area/Waste Storage Area, where primary restoration equals 15 acres of wetland mitigation, resulting in a 1.5 to 1.0 ratio. This is due to DOE's existing regulatory commitment for mitigation of 10 acres of wetlands that will be filled during remedial activities.

The second general assumption is the use of an annual discount rate of 3.00%. This rate applies to both past and future impacts.

2.4 Service Loss Assumptions

Several assumptions are used in estimating service level impacts for each area. First, when information to the contrary is not available, service losses were assumed to have started in 1952, when full-scale operations began at the FEMP. Likewise, excavation impacts are assumed to start entirely within the first year of excavation, based on current remedial design schedules. Excavation impacts are calculated by dividing the future impact acreage (which is also the primary restoration acreage) into the total area acreage to obtain a percent service level loss. Specific details of each of these assumptions is provided in the text for each area calculated.

2.5 Service Gain Assumptions

The assumptions used in the calculation of service level gains are as follows. First, it is assumed that recovery is complete in 20 years for all habitats restored at the site. Some habitats will recover sooner than 20 years, based on the nature of the restored habitat. Also, because existing habitats will be enhanced and/or replaced with better quality habitats through the restoration process, service gains may be estimated above 100%, or baseline conditions. This may still be the case even when it is acknowledged that residual contamination may remain in the soil after remediation and restoration have been completed. If it is determined that the residual contamination will not adversely effect ecological receptors and the quality of the habitat has increased, then the service level may be estimated at above 100%. To calculate service gains through infinity, discounted service gains are calculated and summed for 200 years.

3.0 Results of Habitat Equivalency Analysis

This section outlines the results of the HEA process for each area of the site as evaluated in the NRIA. Each area of the site is divided into a discussion of Assumptions and Results. The HEA worksheets for each area were based on the impacts identified in the NRIA. These impacts (both past and future) are summarized in the discussion of Assumptions for each area. The discussion of Assumptions also points out decisions that were made concerning the timing and severity of impacts in each area so that the HEA worksheet could be completed. The discussion of Results identifies the restoration acreage that will be required to compensate for the impacts in each area. In addition, the Results discussion also references the appropriate sections of the NRRP where specific restoration projects are proposed to address the required restoration acreage.

3.1 Paddys Run Riparian Corridor

The Paddys Run Corridor encompasses approximately 98 acres along the western side of the FEMP. Table 1 provides the HEA worksheet for the Paddys Run Corridor. The following outlines the assumptions that were made in developing the HEA analysis:

3.1.1 Assumptions

- Impacts due to contamination occurred in approximately 10 acres of the Paddys Run Corridor. Impacts are assumed to have initially began in 1953 when production started and uncontrolled runoff began to flow into Paddys Run. This increase resulted in a linear decrease in service levels to 91% in 1961.

- Relocation of Paddys Run near the Waste Pit Area occurred in 1962 causing impact to the stream. A 16% reduction in services to 75% was estimated because the relocation involved approximately 25% of the portion of Paddys Run that receives flow throughout the year (Exhibit D).

- Recovery of the stream channel and adjacent revegetation was assumed to start immediately and is reflected in the HEA worksheet in the following year.

- It was assumed that full recovery of the stream occurred in approximately ~~8~~ 9 years. The service level in 1971 is not at pre-relocation levels because vegetation recovery has not been completed.

- Full recovery of the vegetation was assumed to require 20 years as shown. The service level in 1982 is the same percentage (90%) that would have been present in 1962 had relocation not occurred (Exhibit G).

- The installation of stormwater controls started in ~~1987~~ late 1986, limiting runoff to Paddys Run and increasing the service level ~~slightly~~ 1% from 1987 on.

- ~~Production stopped in 1989 which was also assumed to slightly increase service levels in Paddys Run.~~ Service levels were assumed to increase 1% in 1989 as a result of the Stormwater Retention Basin expansion in late 1988 and the cessation of production in 1989 (Exhibit J).

- Service levels were again assumed to increase 1% in 1992 ~~when~~ as a result of the Waste Pit Area Stormwater Runoff controls ~~were installed~~ installation.

- In 1993, erosion controls using rip rap was installed at the inactive flyash pile which was assumed to slightly decrease service levels 1% due to minor physical impacts. The reduction was also only 1% because Removal Action No. 16 was implemented in 1993 as well, which further controlled runoff from the former production area.

- ~~After installation of the rip rap, it was assumed that the stream recovered quickly and that an increase in service levels occurred as a result.~~

- The remediation of contaminated soil will occur in three stages, beginning in 1997 with the Southern Waste Units remedial activities and ending in 2005. Remediation will result in a significant decrease (22%) in the service level ~~of the corridor~~ due to the clearing of vegetation and excavation of 34 acres of riparian corridor, which is approximately 35% of the entire area. The 27% decrease is added to the 9% baseline decrease in 1996 to get an overall 35% decrease. The service reductions are staggered between 1997, 2000, and 2005 to represent the staged excavation of the corridor.

- Restoration of the corridor is assumed to begin immediately after the last stage of remediation and is reflected in the year following excavation in 2006.
- Recovery of the corridor is assumed to be complete in 20 years when the restored stream and vegetation reaches a reasonable level of maturity.
- The restoration of the corridor is assumed to improve the quality of the corridor over current conditions and thus the service level at completion will exceed 100% to a total of 110%.

3.1.2 Results

Using the impacts outlined in the NRIA, along with the assumptions outlined above, a total of ~~86~~ 87 acres of replacement habitat would be required to compensate for impacts to the Paddys Run Corridor. Impacted areas of the existing riparian corridor and the stream will be restored at the completion of remediation. Additional restoration to compensate for the impacts to the Paddys Run Corridor will focus on the expansion and enhancement of riparian habitat adjacent to the stream. Specific projects proposed as compensation for impacts to Paddys Run are identified in Sections 3.1.2 and 3.2.4 of the NRRP.

Table 1

Draft HEA Analysis for the Paddys Run Corridor
Interim Losses due to Riparian Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	1.85
1953	injury begins	99%	1%	1.5%	3.67	5.5%	5.40
1954		98%	2%	2.5%	3.56	8.9%	8.73
1955		97%	3%	3.5%	3.46	12.1%	11.87
1956		96%	4%	4.5%	3.36	15.1%	14.82
1957		95%	5%	5.5%	3.26	17.9%	17.58
1958		94%	6%	6.5%	3.17	20.6%	20.17
1959		93%	7%	7.5%	3.07	23.1%	22.60
1960		92%	8%	8.5%	2.99	25.4%	24.87
1961		91%	9%	17.0%	2.90	49.3%	48.29
1962	stream relocation	75%	25%	25.0%	2.81	70.3%	68.94
1963	stream recovery begins	75%	25%	25.0%	2.73	68.3%	66.93
1964		75%	25%	25.0%	2.65	66.3%	64.98
1965		75%	25%	25.0%	2.58	64.4%	63.09
1966		75%	25%	24.5%	2.50	61.3%	60.03
1967		76%	24%	23.5%	2.43	57.0%	55.90
1968		77%	23%	22.5%	2.36	53.0%	51.96
1969		78%	22%	21.5%	2.29	49.2%	48.21
1970		79%	21%	20.5%	2.22	45.5%	44.63
1971	stream recovery complete	80%	20%	19.5%	2.16	42.1%	41.21
1972	vegetation recovery continues	81%	19%	18.5%	2.09	38.7%	37.96
1973		82%	18%	17.5%	2.03	35.6%	34.86
1974		83%	17%	16.5%	1.97	32.6%	31.91
1975		84%	16%	15.5%	1.92	29.7%	29.11
1976		85%	15%	14.5%	1.86	27.0%	26.43
1977		86%	14%	13.5%	1.81	24.4%	23.89
1978		87%	13%	12.5%	1.75	21.9%	21.48
1979		88%	12%	11.5%	1.70	19.6%	19.19
1980		89%	11%	11.0%	1.65	18.2%	17.82
1981		89%	11%	10.5%	1.60	16.8%	16.51
1982	vegetation recovery complete	90%	10%	10.0%	1.56	15.6%	15.27
1983		90%	10%	10.0%	1.51	15.1%	14.82
1984		90%	10%	10.0%	1.47	14.7%	14.39
1985		90%	10%	10.0%	1.43	14.3%	13.97
1986		90%	10%	9.5%	1.38	13.2%	12.89
1987	SWRB	91%	9%	9.0%	1.34	12.1%	11.85
1988	SWRB expansion	91%	9%	8.5%	1.30	11.1%	10.87
1989	production stops	92%	8%	8.0%	1.27	10.1%	9.93
1990		92%	8%	8.0%	1.23	9.8%	9.64
1991	[illegible]	92%	8%	7.5%	1.19	9.0%	8.78
1992	waste pits stormwater controls	93%	7%	7.5%	1.16	8.7%	8.52
1993	inactive flyash disposal area R.A.	92%	8%	8.0%	1.13	9.0%	8.82
1994		92%	8%	8.0%	1.09	8.7%	8.57
1995		92%	8%	8.0%	1.06	8.5%	8.32
1996		92%	8%	12.5%	1.03	12.9%	12.62
1997	excavation (SWU)	83%	17%	17.0%	1.00	17.0%	16.66
1998		83%	17%	17.0%	0.97	16.5%	16.17
1999		83%	17%	21.5%	0.94	20.3%	19.86
2000	excavation (waste pits)	74%	26%	26.0%	0.92	23.8%	23.32
2001		74%	26%	26.0%	0.89	23.1%	22.64
2002		74%	26%	26.0%	0.86	22.4%	21.98
2003		74%	26%	26.0%	0.84	21.8%	21.34
2004		74%	26%	30.5%	0.81	24.8%	24.30
2005	excavation remaining areas	65%	35%	35.0%	0.79	27.6%	27.08
2006	primary restoration	65%	35%	34.5%	0.77	26.4%	25.91
2007	recovery begins	66%	34%	32.5%	0.74	24.2%	23.70
2008		69%	31%	29.5%	0.72	21.3%	20.89
2009		72%	28%	26.5%	0.70	18.6%	18.21
2010		75%	25%	23.5%	0.68	16.0%	15.68
2011		78%	22%	20.5%	0.66	13.6%	13.28
2012		81%	19%	17.5%	0.64	11.2%	11.01
2013		84%	16%	15.0%	0.62	9.3%	9.16
2014		86%	14%	13.0%	0.61	7.9%	7.71
2015		88%	12%	11.0%	0.59	6.5%	6.33
2016		90%	10%	9.0%	0.57	5.1%	5.03
2017		92%	8%	7.0%	0.55	3.9%	3.80
2018		94%	6%	5.0%	0.54	2.7%	2.63
2019		96%	4%	3.0%	0.52	1.6%	1.53
2020		98%	2%	1.0%	0.51	0.5%	0.50
2021		100%	0%	-1.0%	0.49	-0.5%	-0.48
2022		102%	-2%	-3.0%	0.48	-1.4%	-1.40
2023		104%	-4%	-5.0%	0.46	-2.3%	-2.27
2024		106%	-6%	-7.0%	0.45	-3.2%	-3.09
2025		108%	-8%	-9.0%	0.44	-3.9%	-3.86
2026	recovery complete	110%	-10%	-10.0%	0.42	-4.2%	-4.16

Total Discounted effective acre-years lost = 1513.95

Draft HEA Analysis for the Paddys Run Riparian Corridor
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2006	primary restoration	65%	65.5%	0.77	0.50
2007	recovery begins	66%	67.5%	0.74	0.50
2008		69%	70.5%	0.72	0.51
2009		72%	73.5%	0.70	0.52
2010		75%	76.5%	0.68	0.52
2011		78%	79.5%	0.66	0.53
2012		81%	82.5%	0.64	0.53
2013		84%	85.0%	0.62	0.53
2014		86%	87.0%	0.61	0.53
2015		88%	89.0%	0.59	0.52
2016		90%	91.0%	0.57	0.52
2017		92%	93.0%	0.55	0.51
2018		94%	95.0%	0.54	0.51
2019		96%	97.0%	0.52	0.51
2020		98%	99.0%	0.51	0.50
2021		100%	101.0%	0.49	0.50
2022		102%	103.0%	0.48	0.49
2023		104%	105.0%	0.46	0.49
2024		106%	107.0%	0.45	0.48
2025		108%	109.0%	0.44	0.48
2026	recovery complete	110%	110.0%	0.42	0.47
2027	to infinity	110%	110.0%	na	17.92

Total gain in discounted effective acre-years/acre = 28.56

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 1513.95

Present discounted gain in effective acre-years/acre (G) = 28.56

Acres of replacement habitat required for compensation (R, R=L/G) = 53.02

Total restoration acreage required = $\boxed{87.02}$

Related Information

Total acres of riparian habitat = 98

Acres of revegetation for the primary restoration project = 34

Annual discount rate = 3.00%

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3.2 Northern Woodlot and Northern Pine Plantation

The Northern Woodlots include approximately 60 acres of the Northern Pine Plantation and an additional 100 acres of mixed deciduous forest including a forested wetland. The HEA worksheet for this area is outlined in Table 2 and the assumptions utilized are as follows:

3.2.1 Assumptions

- Injury was assumed to begin in 1953 ~~and effected 4.0 acres of the Northern Woodlot and pines. Impacts were the~~ as a result of airborne deposition of contaminants from production operations, causing a ~~slight~~ linear decrease in service levels to 95% in 1957.

- There were minor physical impacts to the area at various points in time, but these were not directly linked to a release and were not factored into HEA as a loss of service.

- A portion of the northern woodlots was cleared in 1988 for use as borrow material. This impact resulted in a 4% decrease in services for 1988 and subsequent years. The impact is not calculated as a percent acreage loss since the acres cleared are not included in the 162 acre present-day configuration of the northern woodlots (Exhibit I).

- The Northern Pine Plantation was planted in 1972, but was not considered as a beneficial habitat until 1987 when the plantation reached a reasonable state of maturity. ~~An~~ A 1% increase in service levels was included at that point (Exhibit I).

- Excavation activities to support the OSDF will be initiated in 1997 with the clearing of approximately 40 acres of the Northern Pines resulting in a ~~significant~~ drop in service level ~~provided~~ to 75%. This service level is estimated by dividing the impacted acres (40) by the total area (162 acres). The area of the Northern Woodlots that will be impacted will be utilized for the OSDF.

- Restoration will be initiated in the year 2002 and will involve enhancing other areas of the Northern Woodlot.

- Due to the maturity of the habitat in much of the Northern Woodlot, it was assumed that only 15 years would be necessary for full recovery (i.e., maturity) of the area.

- The restoration of the woodlots is assumed to improve the quality of the woodlots over current conditions, thus the service level at completion will exceed 100% (to a total of 106%).

3.2.2 Results

Based on the acres of impacts outlined in the assumptions listed above regarding loss of services, a total of 74 acres of restoration will be required to compensate for impacts to the Northern Woodlots. The area of primary impact in the Northern Woodlot will not be available for restoration due to utilization by the OSDF. Therefore, restoration activities outlined in the NRRP in Sections 3.1.4 and 3.1.5 will focus on enhancing other areas of the Northern Woodlot. 2

Table 2

Draft HEA Analysis for the Northern Woodlots
Interim Losses due to Northern Woodlot Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	3.06
1953	injury begins	99%	1%	1.5%	3.67	5.5%	8.92
1954		98%	2%	2.5%	3.56	8.9%	14.44
1955		97%	3%	3.5%	3.46	12.1%	19.62
1956		96%	4%	4.5%	3.36	15.1%	24.49
1957		95%	5%	5.0%	3.26	16.3%	26.42
1958		95%	5%	5.0%	3.17	15.8%	25.65
1959		95%	5%	5.0%	3.07	15.4%	24.91
1960		95%	5%	5.0%	2.99	14.9%	24.18
1961		95%	5%	5.0%	2.90	14.5%	23.48
1962		95%	5%	5.0%	2.81	14.1%	22.79
1963		95%	5%	5.0%	2.73	13.7%	22.13
1964		95%	5%	5.0%	2.65	13.3%	21.48
1965		95%	5%	5.0%	2.58	12.9%	20.86
1966		95%	5%	5.0%	2.50	12.5%	20.25
1967		95%	5%	5.0%	2.43	12.1%	19.66
1968		95%	5%	5.0%	2.36	11.8%	19.09
1969		95%	5%	5.0%	2.29	11.4%	18.53
1970		95%	5%	5.0%	2.22	11.1%	17.99
1971		95%	5%	5.0%	2.16	10.8%	17.47
1972	north pine plantation planted	95%	5%	5.0%	2.09	10.5%	16.96
1973		95%	5%	5.0%	2.03	10.2%	16.47
1974		95%	5%	5.0%	1.97	9.9%	15.99
1975		95%	5%	5.0%	1.92	9.6%	15.52
1976		95%	5%	5.0%	1.86	9.3%	15.07
1977		95%	5%	5.0%	1.81	9.0%	14.63
1978		95%	5%	5.0%	1.75	8.8%	14.20
1979		95%	5%	5.0%	1.70	8.5%	13.79
1980		95%	5%	5.0%	1.65	8.3%	13.39
1981		95%	5%	5.0%	1.60	8.0%	13.00
1982		95%	5%	5.0%	1.56	7.8%	12.62
1983		95%	5%	5.0%	1.51	7.6%	12.25
1984		95%	5%	5.0%	1.47	7.3%	11.90
1985		95%	5%	5.0%	1.43	7.1%	11.55
1986		95%	5%	4.5%	1.38	6.2%	10.09
1987	NPP habitat service increase	96%	4%	6.0%	1.34	8.1%	13.06
1988	ground clearing for borrow area	92%	8%	8.0%	1.30	10.4%	16.91
1989		92%	8%	8.0%	1.27	10.1%	16.42
1990		92%	8%	8.0%	1.23	9.8%	15.94
1991		92%	8%	8.0%	1.19	9.6%	15.47
1992		92%	8%	8.0%	1.16	9.3%	15.02
1993		92%	8%	8.0%	1.13	9.0%	14.59
1994		92%	8%	8.0%	1.09	8.7%	14.16
1995		92%	8%	8.0%	1.06	8.5%	13.75
1996		92%	8%	16.5%	1.03	17.0%	27.53
1997	excavation	75%	25%	25.0%	1.00	25.0%	40.50
1998		75%	25%	25.0%	0.97	24.3%	39.32
1999		75%	25%	25.0%	0.94	23.6%	38.18
2000		75%	25%	25.0%	0.92	22.9%	37.06
2001		75%	25%	25.0%	0.89	22.2%	35.98
2002	primary restoration	75%	25%	23.5%	0.86	20.3%	32.84
2003	recovery begins	78%	22%	21.0%	0.84	17.6%	28.49
2004		80%	20%	19.0%	0.81	15.4%	25.03
2005		82%	18%	17.0%	0.79	13.4%	21.74
2006		84%	16%	15.0%	0.77	11.5%	18.62
2007		86%	14%	13.0%	0.74	9.7%	15.67
2008		88%	12%	11.0%	0.72	7.9%	12.87
2009		90%	10%	9.0%	0.70	6.3%	10.23
2010		92%	8%	7.0%	0.68	4.8%	7.72
2011		94%	6%	5.0%	0.66	3.3%	5.36
2012		96%	4%	3.0%	0.64	1.9%	3.12
2013		98%	2%	1.0%	0.62	0.6%	1.01
2014		100%	0%	-1.0%	0.61	-0.6%	-0.98
2015		102%	-2%	-3.0%	0.59	-1.8%	-2.85
2016		104%	-4%	-5.0%	0.57	-2.9%	-4.62
2017	recovery complete	106%	-6%	-6.0%	0.55	-3.3%	-5.38

Total Discounted effective acre-years lost = 1125.61

Draft HEA Analysis for the Northern Woodlots
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2002	primary restoration	75%	78.8%	0.86	0.68
2003	recovery begins	78%	81.0%	0.84	0.68
2004		80%	83.0%	0.81	0.67
2005		82%	83.0%	0.79	0.66
2006		84%	85.0%	0.77	0.65
2007		86%	87.0%	0.74	0.65
2008		88%	89.0%	0.72	0.64
2009		90%	91.0%	0.70	0.64
2010		92%	93.0%	0.68	0.63
2011		94%	95.0%	0.66	0.63
2012		96%	97.0%	0.64	0.62
2013		98%	99.0%	0.62	0.62
2014		100%	101.0%	0.61	0.61
2015		102%	103.0%	0.59	0.61
2016		104%	105.0%	0.57	0.60
2017	recovery complete	106%	106.0%	0.55	0.59
2018	to infinity	106%	106.0%	na	22.53

Total gain in discounted effective acre-years/acre = 32.70

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 1125.61

Present discounted gain in effective acre-years/acre (G) = 32.70

Acres of replacement habitat required for compensation (R, R=L/G) = 34.42

Total restoration acreage required = $\boxed{74.42}$

Related Information

Total acres of north woodlot habitat = 162

Acres of revegetation for the primary restoration project = 40

Annual discount rate = 3.00%

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3.3 Southern Pines and Waste Units

The Southern Pines and Waste Units encompasses approximately 66 acres south-west of the former production area. Table 3 provides the HEA worksheet for the Southern Pines and Waste Units. Assumptions used in the HEA for this area are as follows:

3.3.1 Assumptions

- ~~The impacts beginning in 1953 were focused on runoff through the Pilot Plant Drainage Ditch resulting in contamination and physical disposal of contaminated material in the Fly ash piles and South Field Areas, which affected 40 acres.~~

- Injury was assumed to begin in 1953 as a result of production runoff into the Pilot Plant Drainage Ditch and due to the use of the Inactive Flyash Pile and Southfield as a disposal area, which caused a linear reduction in services to 85% in 1960 (Exhibit C).

- The initiation of the Active Flyash Pile in 1966 resulted in a 5% reduction in services to 80%. The 5% reduction is estimated by determining the percentage of the Southern Pines and Waste Units that the Active Flyash Pile represents (5 acres/66 acres, or 7.5%) and modifying that percent based on a subjective increase in service level due to the closure of the Inactive Flyash Pile and Southfield (Exhibit E).

- ~~A resultant decrease in~~ The 80% service levels ~~is identified~~ continues until use of the inactive Fly ash pile in 1965 is terminated and successional growth begins to take over in approximately 1970 ~~(exhibit _)~~ (Exhibit E). In 1970, service levels show a linear increase to 90% in 1979. This represents a 15 year recovery to an old field habitat.

- ~~Additional increases in service levels were assumed to occur after the Southern Pine Plantation was planted in 1972 (exhibit _). The NRRP reference for this project is in Section 3.1.3 .~~

- The Southern Pine Plantation was planted in 1972, but was not considered a beneficial habitat until 1987, when the plantation reached a reasonable state of maturity. A 2% increase in service level was included at this point. Note that while the habitats and time frames are similar, the Southern Pine Plantation provides more benefit (as reflected in service level increases) because it represents a greater percentage of the overall area (Exhibit J).

- The clearing of several areas in the Southern Pines occurred in the 1990's resulting in additional decreases in service levels.

- A ~~significant~~ 15% decline in service level is assumed to occur when the Southern Waste Units are excavated, due to the clearing of 17 acres of successional growth in 1998. The 15% decline results in a 73% service level, which is approximately the percentage of the area that is to be excavated (17 acres/66 acres).

- These areas are assumed to provide beneficial habitat even though they are contaminated.

- Restoration of this area will occur ~~immediately following remediation~~ in the year 2001.
- The recovery period is expected to be approximately 20 years until a reasonable level of maturity is achieved (100% service level).

3.3.2 Results

Using the above-listed assumptions and the acres of impact from the NRIA, 49 acres of restoration will be required to compensate for impacts to the Southern Pines and Waste Units. The NRRP references projects to be implemented for impact compensation in Sections 3.1.3 and 3.2.4.

Table 3

Draft HEA Analysis for the Southern Pines and Waste Units
Interim Losses due to Southern Pines and Waste Units Habitat Injury

Year	Project Status	% Service Level	% Service Loss	vg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	1.0%	3.78	3.8%	2.50
1953	injury begins	98%	2%	3.0%	3.67	11.0%	7.27
1954		96%	4%	5.0%	3.56	17.8%	11.76
1955		94%	6%	7.0%	3.46	24.2%	15.99
1956		92%	8%	9.0%	3.36	30.2%	19.96
1957		90%	10%	11.0%	3.26	35.9%	23.68
1958		88%	12%	13.0%	3.17	41.2%	27.17
1959		86%	14%	14.5%	3.07	44.6%	29.43
1960		85%	15%	15.0%	2.99	44.8%	29.55
1961		85%	15%	15.0%	2.90	43.5%	28.69
1962		85%	15%	15.0%	2.81	42.2%	27.86
1963		85%	15%	15.0%	2.73	41.0%	27.05
1964		85%	15%	15.0%	2.65	39.8%	26.26
1965	cessation of disposal activities	85%	15%	17.5%	2.58	45.1%	29.74
1966	active flyash pile initiated	80%	20%	20.0%	2.50	50.0%	33.00
1967		80%	20%	20.0%	2.43	48.5%	32.04
1968		80%	20%	20.0%	2.36	47.1%	31.11
1969		80%	20%	19.5%	2.29	44.6%	29.45
1970	successional growth in S.W.U.	81%	19%	18.5%	2.22	41.1%	27.12
1971		82%	18%	17.5%	2.16	37.7%	24.91
1972	south pine plantation planted	83%	17%	16.5%	2.09	34.5%	22.80
1973		84%	16%	15.5%	2.03	31.5%	20.80
1974		85%	15%	14.5%	1.97	28.6%	18.89
1975		86%	14%	13.5%	1.92	25.9%	17.07
1976		87%	13%	12.5%	1.86	23.3%	15.35
1977		88%	12%	11.5%	1.81	20.8%	13.71
1978		89%	11%	10.5%	1.75	18.4%	12.15
1979		90%	10%	10.0%	1.70	17.0%	11.24
1980		90%	10%	10.0%	1.65	16.5%	10.91
1981		90%	10%	10.0%	1.60	16.0%	10.59
1982		90%	10%	10.0%	1.56	15.6%	10.28
1983		90%	10%	10.0%	1.51	15.1%	9.98
1984		90%	10%	10.0%	1.47	14.7%	9.69
1985		90%	10%	10.0%	1.43	14.3%	9.41
1986		90%	10%	9.0%	1.38	12.5%	8.22
1987	SPP habitat increase	92%	8%	8.0%	1.34	10.8%	7.10
1988		92%	8%	8.0%	1.30	10.4%	6.89
1989		92%	8%	8.0%	1.27	10.1%	6.69
1990		92%	8%	8.0%	1.23	9.8%	6.49
1991		92%	8%	9.0%	1.19	10.7%	7.09
1992	clearing for Met. tower	90%	10%	10.0%	1.16	11.6%	7.65
1993		90%	10%	10.0%	1.13	11.3%	7.43
1994		90%	10%	11.0%	1.09	12.0%	7.93
1995	clearing for Bldg. 45 access road	88%	12%	12.0%	1.06	12.7%	8.40
1996		88%	12%	12.0%	1.03	12.4%	8.16
1997		88%	12%	19.5%	1.00	19.5%	12.87
1998	excavation	73%	27%	27.0%	0.97	26.2%	17.30
1999	[illegible]	73%	27%	27.0%	0.94	25.5%	16.80
2000		73%	27%	27.0%	0.92	24.7%	16.31
2001	primary restoration	73%	27%	27.0%	0.89	24.0%	15.83
2002	recovery begins	73%	27%	26.5%	0.86	22.9%	15.09
2003		74%	26%	25.5%	0.84	21.4%	14.09
2004		75%	25%	24.5%	0.81	19.9%	13.15
2005		76%	24%	23.5%	0.79	18.6%	12.24
2006		77%	23%	22.5%	0.77	17.2%	11.38
2007		78%	22%	21.5%	0.74	16.0%	10.56
2008		79%	21%	20.5%	0.72	14.8%	9.77
2009		80%	20%	19.5%	0.70	13.7%	9.03
2010		81%	19%	18.5%	0.68	12.6%	8.31
2011		82%	18%	17.5%	0.66	11.6%	7.64
2012		83%	17%	16.5%	0.64	10.6%	6.99
2013		84%	16%	15.5%	0.62	9.7%	6.37
2014		85%	15%	13.5%	0.61	8.2%	5.39
2015		88%	12%	11.0%	0.59	6.5%	4.26
2016		90%	10%	9.0%	0.57	5.1%	3.39
2017		92%	8%	7.0%	0.55	3.9%	2.56
2018		94%	6%	5.0%	0.54	2.7%	1.77
2019		96%	4%	3.0%	0.52	1.6%	1.03
2020		98%	2%	1.0%	0.51	0.5%	0.33
2021	recovery complete	100%	0%	0.0%	0.49	0.0%	0.00

Total Discounted effective acre-years lost = 981.93

Draft HEA Analysis for the Southern Pines and Waste Units
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2001	primary restoration	73%	73.0%	0.89	0.65
2002	recovery begins	73%	73.5%	0.86	0.63
2003		74%	74.5%	0.84	0.62
2004		75%	75.5%	0.81	0.61
2005		76%	76.5%	0.79	0.60
2006		77%	77.5%	0.77	0.59
2007		78%	78.5%	0.74	0.58
2008		79%	79.5%	0.72	0.57
2009		80%	80.5%	0.70	0.56
2010		81%	81.5%	0.68	0.55
2011		82%	82.5%	0.66	0.55
2012		83%	83.5%	0.64	0.54
2013		84%	84.5%	0.62	0.53
2014		85%	86.5%	0.61	0.52
2015		88%	89.0%	0.59	0.52
2016		90%	91.0%	0.57	0.52
2017		92%	93.0%	0.55	0.51
2018		94%	95.0%	0.54	0.51
2019		96%	97.0%	0.52	0.51
2020		98%	99.0%	0.51	0.50
2021	recovery complete	100%	100.0%	0.49	0.49
2022	to infinity	100%	100.0%	na	18.88

Total gain in discounted effective acre-years/acre = 30.57

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 981.93

Present discounted gain in effective acre-years/acre (G) = 30.57

Acres of replacement habitat required for compensation (R, R=L/G) = 32.12

Total restoration acreage required = $\boxed{49.12}$

Related Information

Total acres of southern pines and waste units habitat = 66

Acres of revegetation for the primary restoration project = 17

Annual discount rate = 3.00%

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3.4 Grasslands

The Grasslands encompass approximately 235 acres in the eastern and southern portions of the FEMP. Table 4 provides the HEA worksheets for this area. The following provides the assumptions that were utilized in developing the HEA for the Grassland Areas:

3.4.1 Assumptions

- Production operations ~~including operation of the Sewage Treatment Plant Incinerator,~~ resulted in air deposition contaminating approximately 93 acres of grassland areas which is identified by a slight decrease in service levels ~~starting~~ to 98% in 1953~~4~~. The reason only a 2% reduction is estimated is because of the limited habitat services the grasslands provide.

- Use of the Trap Range starting around 1960 resulted in lead contamination in an isolated portion of the grasslands which is also reflected by decreased service levels to 96% (Exhibit D).

- It is assumed that service levels essentially remained constant until contaminated soil was excavated along with approximately ~~10~~ 5 acres of off property woodlot as part of Removal Action 14 in 1992. This resulted in an additional 2% reduction in services.

- A significant decrease in service levels was assumed to occur with the excavation of Area 1, Phase I in 1996. From 1996 to 2004, grassland excavations are staggered and reduced linearly to reflect the large scale excavations that will be taking place. The staggered reductions for the different phases of excavation (Area 1 Phase 1, Area 1 Phase 2, and Area 2 Phase 2) are based on qualitative estimates of the ration of a given phase to the overall acreage of the grasslands.

- In the year 2002 it is anticipated that almost all grassland areas (approximately 204 acres) will be excavated as reflected by the decrease to a 12% service level.

- The restoration of the grassland areas will occur where possible; however, a significant portion will be utilized for the OSDF and unavailable for restoration.

- It is assumed that restoration will occur in approximately 2005 at the time that use of the borrow area and Excavation of Area 2, Phase 2 is complete.

- The recovery for the restoration of the grassland area is assumed to be approximately 5 years since portions of the area will be converted to native prairies and wetlands which are assumed to have less maturation time than an area of exclusively forest habitat. The recovery is assumed to be linear to a 110% service level, since restored prairies and wetlands will provide higher quality habitat than the present-day introduced grasslands.

3.4.2 Results

Based on the acres of impact identified in the NRIA coupled with the assumptions that have been made above regarding loss of services, a total of 283 acres of restoration is required to compensate for impacts to grassland areas. Restoration of the grassland areas will be focused on the borrow area, southern portions of the site and the buffer around the OSDF. Proposed restoration projects area outlined in Sections 3.2.5 and 3.2.6 in the NRRP and would focus on the establishment of a mosaic of wetland/open water, woodland and prairie habitats.

Table 4

Draft HEA Analysis for the Grasslands
Interim Losses due to Grasslands Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	4.44
1953	injury begins	99%	1%	1.5%	3.67	5.5%	12.94
1954		98%	2%	2.0%	3.56	7.1%	16.75
1955		98%	2%	2.0%	3.46	6.9%	16.27
1956		98%	2%	2.0%	3.36	6.7%	15.79
1957		98%	2%	2.0%	3.26	6.5%	15.33
1958		98%	2%	2.0%	3.17	6.3%	14.89
1959		98%	2%	3.0%	3.07	9.2%	21.68
1960	use of trap range initiated	96%	4%	4.0%	2.99	11.9%	28.06
1961		96%	4%	4.0%	2.90	11.6%	27.24
1962		96%	4%	4.0%	2.81	11.3%	26.45
1963		96%	4%	4.0%	2.73	10.9%	25.68
1964		96%	4%	4.0%	2.65	10.6%	24.93
1965		96%	4%	4.0%	2.58	10.3%	24.21
1966		96%	4%	4.0%	2.50	10.0%	23.50
1967		96%	4%	4.0%	2.43	9.7%	22.82
1968		96%	4%	4.0%	2.36	9.4%	22.15
1969		96%	4%	4.0%	2.29	9.2%	21.51
1970		96%	4%	4.0%	2.22	8.9%	20.88
1971		96%	4%	4.0%	2.16	8.6%	20.27
1972		96%	4%	4.0%	2.09	8.4%	19.68
1973		96%	4%	4.0%	2.03	8.1%	19.11
1974		96%	4%	4.0%	1.97	7.9%	18.55
1975		96%	4%	4.0%	1.92	7.7%	18.01
1976		96%	4%	4.0%	1.86	7.4%	17.49
1977		96%	4%	4.0%	1.81	7.2%	16.98
1978		96%	4%	4.0%	1.75	7.0%	16.48
1979		96%	4%	4.0%	1.70	6.8%	16.00
1980		96%	4%	4.0%	1.65	6.6%	15.54
1981		96%	4%	4.0%	1.60	6.4%	15.08
1982		96%	4%	4.0%	1.56	6.2%	14.64
1983		96%	4%	4.0%	1.51	6.1%	14.22
1984		96%	4%	4.0%	1.47	5.9%	13.80
1985		96%	4%	4.0%	1.43	5.7%	13.40
1986		96%	4%	4.0%	1.38	5.5%	13.01
1987		96%	4%	4.0%	1.34	5.4%	12.63
1988		96%	4%	4.0%	1.30	5.2%	12.26
1989		96%	4%	4.0%	1.27	5.1%	11.91
1990		96%	4%	4.0%	1.23	4.9%	11.56
1991		96%	4%	4.5%	1.19	5.4%	12.63
1992	Removal Action No. 14	95%	5%	4.5%	1.16	5.2%	12.26
1993		96%	4%	4.0%	1.13	4.5%	10.58
1994		96%	4%	4.0%	1.09	4.4%	10.27
1995		96%	4%	20.0%	1.06	21.2%	49.86
1996	A1P1 excavation	64%	36%	36.0%	1.03	37.1%	87.14
1997		64%	36%	53.0%	1.00	53.0%	124.55
1998	A1P2 excavation	30%	70%	70.5%	0.97	68.4%	160.85
1999		29%	71%	71.5%	0.94	67.4%	158.38
2000		28%	72%	72.5%	0.92	66.3%	155.92
2001		27%	73%	79.5%	0.89	70.6%	165.99
2002	A2P2 excavation	14%	86%	86.5%	0.86	74.6%	175.35
2003		13%	87%	87.0%	0.84	72.9%	171.22
2004		13%	87%	87.0%	0.81	70.7%	166.24
2005	primary restoration	13%	87%	83.5%	0.79	65.9%	154.90
2006	recovery begins	20%	80%	65.0%	0.77	49.8%	117.07
2007		50%	50%	37.5%	0.74	27.9%	65.57
2008		75%	25%	12.5%	0.72	9.0%	21.22
2009		100%	0%	-5.0%	0.70	-3.5%	-8.24
2010	recovery complete	110%	-10%	-10.0%	0.68	-6.8%	-16.00

Total Discounted effective acre-years lost = 2491.92

Draft HEA Analysis for the Grasslands
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2005	primary restoration	12%	16.0%	0.79	0.13
2006	recovery begins	20%	35.0%	0.77	0.27
2007		50%	62.5%	0.74	0.47
2008		75%	87.5%	0.72	0.63
2009		100%	105.0%	0.70	0.74
2010	recovery complete	110%	110.0%	0.68	0.75
2011	to infinity	110%	110.0%	na	28.76

Total gain in discounted effective acre-years/acre = 31.74

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 2491.92

Present discounted gain in effective acre-years/acre (G) = 31.74

Acres of replacement habitat required for compensation (R, R=L/G) = 78.52

Total restoration acreage required = 282.52

Related Information

Total acres of grassland habitat = 235

Acres of revegetation for the primary restoration project = 204

Annual discount rate = 3.00%

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3.5 Waste Storage/Production Area

The Waste Storage Area encompasses approximately 37 acres adjacent to the ~~former~~ production areas. The Production Area encompasses approximately 136 acres in the center of the FEMP. Table 5 provides the HEA worksheet for these areas. The assumptions used in developing the HEA data for this area are as follows:

3.5.1 Assumptions

- The Waste Storage Area and Production Area provided very little habitat as both were disturbed as part of construction of the site (Exhibit C).

- ~~Both areas were contaminated and were assumed to contribute to potential ecological risks due to above BTV concentrations.~~ It is assumed that both areas were impacted in their entirety due to contamination from site operations.

- A linear decrease in service level to 95% in 1957 is identified beginning in 1953~~; however,~~. Decreases are not as significant due to the lack of good habitat in both areas.

- After ~~an~~ the initial 5% decrease in service levels in the early years of production, service levels are assumed to remain constant until remediation begins in these areas.

- Remediation of the areas is assumed to impact the entire area and result in a ~~slight~~ 5% decrease in service levels starting in 1999~~; however, this was assumed to be relatively minor due to a lack of quality habitat.~~ with a linear reduction to 89% service level in 2000. The 89% service level is calculated from the percentage of wetlands impacted (10 acres/173 acres, or 6%), which is added to the baseline 5% impact.

- The recovery of the area after remediation, is assumed to require approximately 15 years for full maturation of the habitat. Service levels are estimated to increase to 150% because the mitigated, contiguous wetland system will provide more quality habitat than the unmanaged, fragmented drainage ditches that encompass the majority of the 10 acres of wetlands.

3.5.2 Results

A total of 31 acres will be required to compensate for impacts given the above assumptions. Restoration of the Waste Storage/Production Area will focus on the conversion of excavated areas into wetland/open water habitat where possible, and revegetating other areas. Proposed restoration projects are outlined in sections 3.2.2 and 3.2.3 of the NRRP.

Table 5

Draft HEA Analysis for the Waste Storage/Production Area
Interim Losses due to Production/Waste Storage Area Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	3.27
1953	injury begins	99%	1%	1.5%	3.67	5.5%	9.53
1954		98%	2%	2.5%	3.56	8.9%	15.42
1955		97%	3%	3.5%	3.46	12.1%	20.95
1956		96%	4%	4.5%	3.36	15.1%	26.16
1957		95%	5%	5.0%	3.26	16.3%	28.22
1958		95%	5%	5.0%	3.17	15.8%	27.39
1959		95%	5%	5.0%	3.07	15.4%	26.60
1960		95%	5%	5.0%	2.99	14.9%	25.82
1961		95%	5%	5.0%	2.90	14.5%	25.07
1962		95%	5%	5.0%	2.81	14.1%	24.34
1963		95%	5%	5.0%	2.73	13.7%	23.63
1964		95%	5%	5.0%	2.65	13.3%	22.94
1965		95%	5%	5.0%	2.58	12.9%	22.27
1966		95%	5%	5.0%	2.50	12.5%	21.63
1967		95%	5%	5.0%	2.43	12.1%	21.00
1968		95%	5%	5.0%	2.36	11.8%	20.38
1969		95%	5%	5.0%	2.29	11.4%	19.79
1970		95%	5%	5.0%	2.22	11.1%	19.21
1971		95%	5%	5.0%	2.16	10.8%	18.65
1972		95%	5%	5.0%	2.09	10.5%	18.11
1973		95%	5%	5.0%	2.03	10.2%	17.58
1974		95%	5%	5.0%	1.97	9.9%	17.07
1975		95%	5%	5.0%	1.92	9.6%	16.57
1976		95%	5%	5.0%	1.86	9.3%	16.09
1977		95%	5%	5.0%	1.81	9.0%	15.62
1978		95%	5%	5.0%	1.75	8.8%	15.17
1979		95%	5%	5.0%	1.70	8.5%	14.73
1980		95%	5%	5.0%	1.65	8.3%	14.30
1981		95%	5%	5.0%	1.60	8.0%	13.88
1982		95%	5%	5.0%	1.56	7.8%	13.48
1983		95%	5%	5.0%	1.51	7.6%	13.08
1984		95%	5%	5.0%	1.47	7.3%	12.70
1985		95%	5%	5.0%	1.43	7.1%	12.33
1986		95%	5%	5.0%	1.38	6.9%	11.97
1987		95%	5%	5.0%	1.34	6.7%	11.62
1988		95%	5%	5.0%	1.30	6.5%	11.29
1989		95%	5%	5.0%	1.27	6.3%	10.96
1990		95%	5%	5.0%	1.23	6.1%	10.64
1991		95%	5%	5.0%	1.19	6.0%	10.33
1992		95%	5%	5.0%	1.16	5.8%	10.03
1993		95%	5%	5.0%	1.13	5.6%	9.74
1994		95%	5%	5.0%	1.09	5.5%	9.45
1995		95%	5%	5.0%	1.06	5.3%	9.18
1996		95%	5%	5.0%	1.03	5.2%	8.91
1997		95%	5%	5.0%	1.00	5.0%	8.65
1998		95%	5%	7.5%	0.97	7.3%	12.60
1999	excavation	90%	10%	10.5%	0.94	9.9%	17.12
2000		89%	11%	11.0%	0.92	10.1%	17.42
2001		89%	11%	11.0%	0.89	9.8%	16.91
2002		89%	11%	11.0%	0.86	9.5%	16.42
2003		89%	11%	11.0%	0.84	9.2%	15.94
2004		89%	11%	11.0%	0.81	8.9%	15.47
2005	primary restoration	89%	11%	11.0%	0.79	8.7%	15.02
2006	recovery begins	89%	11%	11.0%	0.77	8.4%	14.58
2007		89%	11%	10.5%	0.74	7.8%	13.52
2008		90%	10%	7.5%	0.72	5.4%	9.37
2009		95%	5%	2.5%	0.70	1.8%	3.03
2010		100%	0%	-2.5%	0.68	-1.7%	-2.95
2011		105%	-5%	-7.5%	0.66	-5.0%	-8.58
2012		110%	-10%	-12.5%	0.64	-8.0%	-13.88
2013		115%	-15%	-17.5%	0.62	-10.9%	-18.87
2014		120%	-20%	-22.5%	0.61	-13.6%	-23.55
2015		125%	-25%	-27.5%	0.59	-16.2%	-27.95
2016		130%	-30%	-32.5%	0.57	-18.5%	-32.06
2017		135%	-35%	-37.5%	0.55	-20.8%	-35.92
2018		140%	-40%	-42.5%	0.54	-22.8%	-39.52
2019		145%	-45%	-47.5%	0.52	-24.8%	-42.89
2020	recovery complete	150%	-50%	-50.0%	0.51	-25.3%	-43.83

Total Discounted effective acre-years lost = 633.17

Draft HEA Analysis for the Waste Storage/Production Area
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2005	primary restoration	89%	89.0%	0.79	0.70
2006	recovery begins	89%	89.0%	0.77	0.68
2007		89%	89.5%	0.74	0.67
2008		90%	92.5%	0.72	0.67
2009		95%	97.5%	0.70	0.68
2010		100%	102.5%	0.68	0.70
2011		105%	107.5%	0.66	0.71
2012		110%	112.5%	0.64	0.72
2013		115%	117.5%	0.62	0.73
2014		120%	122.5%	0.61	0.74
2015		125%	127.5%	0.59	0.75
2016		130%	132.5%	0.57	0.76
2017		135%	137.5%	0.55	0.76
2018		140%	142.5%	0.54	0.77
2019		145%	147.5%	0.52	0.77
2020	recovery complete	150%	150.0%	0.51	0.76
2021	to infinity	150%	150.0%	na	29.18

Total gain in discounted effective acre-years/acre = 40.75

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 633.17

Present discounted gain in effective acre-years/acre (G) = 40.75

Acres of replacement habitat required for compensation (R, R=L/G) = 15.54

Total restoration acreage required = 30.54

Related Information

Total acres of production area/waste storage area habitat = 173

Acres of revegetation for the primary restoration project = 15

Annual discount rate = 3.00%

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3.6 Great Miami Aquifer

The Great Miami Aquifer (GMA) is present under the entire extent of the FEMP. The GMA is not considered a habitat; however, it is a significant natural resource and there is a need to quantify impacts to the GMA. Because the aerial extent of the groundwater was known, the HEA process was determined to be feasible for calculating required restoration acreage to compensate for impacts. Table 6 provides the HEA worksheet for the Great Miami Aquifer. The assumptions used in calculating the HEA worksheet are outlined below:

3.6.1 Assumptions

- ~~Impacts to the GMA were assumed to begin in 1953 when the Waste Storage Area began to be utilized for disposal and production operations began to contribute contamination to the aquifer.~~

- ~~Subsequent impacts to the GMA were identified in 1958 (one year after installation) when use of the Inactive Flyash Pile began and again in 1966 with the use of the Active Flyash Pile.~~

- The six distinct plumes contributing to the GMA were each assumed to result in an initial 5% linear reduction. Therefore, the initiation of three plumes in 1953 results in a 3% annual loss over five years to 85% in 1957 (3*5%, or a 15% loss). This method is continued for two more plumes in 1958, where a 2% loss is shown for the next five years. Finally, the last plume(starting in 1966) results in an overall decrease to 70% in 1970.

- ~~S~~ From 1970, service levels were assumed to continue ~~to~~ a linear decline until 1987, when the Stormwater Retention Basin (SWRB) was installed. ~~Releases continued from the Waste Storage Areas and Fly Ash Piles. The total extent of impact to the GMA from above FRL contamination covered 172 acres.~~ A slight increase of 1% resulted from the control of runoff into Paddys Run.

- ~~An~~ A 2% increase in service levels was assumed to occur in 1989 when production operations were stopped and direct contribution of contaminants to the GMA from the production area stopped also.

- The Alternate Water Supply which provided clean water to local businesses/homes in 1990 was also assumed to provide ~~some compensation for groundwater impacts~~ a 3% gain in service levels.

- The Stormwater Retention Basin expansion in 1992 led to a further 2% increase in service levels.

- Removal Action No. 3 and Waste Storage Area stormwater controls were initiated in 1992 to remove contaminated groundwater from the leading edge of the South Uranium Plume. Removal Action No. 3 was also assumed to compensate for groundwater impacts and ~~an~~ a 5% increase in service levels is identified.

- The installation of the Public Water Supply in 1996 is assumed to provide additional compensation for groundwater impacts and subsequently increases service levels by 8% to 65%.

- The initiation of remediation of the GMA in 1998 is assumed to increase service levels back to near original levels after the 10-year life of the project.

- ~~It is assumed that residual contamination will result in a continued loss in services.~~ The 95% service level at completion in 2009 recognizes the fact that residual uranium contamination below the 20 $\mu g/l$ FRL will continue to be present in the GMA after remediation has been completed.

- Impacts to 96 acres of perched groundwater are included in the service levels for the GMA.

- Less than 1 acre of impact to the Great Miami River due to the FEMP outfall line is included in the service levels for the GMA.

3.6.2 Results

In order to compensate for impacts to the GMA, a total of 329 acres of restoration will be required given the above assumptions. Restoration activities to compensate for impacts to the GMA will center around expansion and enhancement of the riparian corridor rather than addition restoration of the GMA. The expansion of the riparian corridor, coupled with the creation of additional wetland/open water area within Paddys Run watershed are proposed to compensate for GMA impacts. The NRRP proposes restoration projects to compensate for the GMA in Sections 3.2.1 - 3.3.3.

Table 6

Draft HEA Analysis for theGreat Miami Aquifer
Interim Losses due to the Great Miami Aquifer Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	1.5%	3.78	5.7%	9.76
1953	Waste Storage Area, PR, Plt. 6	97%	3%	4.5%	3.67	16.5%	28.42
1954		94%	6%	7.5%	3.56	26.7%	45.98
1955		91%	9%	10.5%	3.46	36.3%	62.50
1956		88%	12%	13.5%	3.36	45.4%	78.02
1957		85%	15%	16.0%	3.26	52.2%	89.77
1958	Inactive Flyash Pile, Southfield	83%	17%	18.0%	3.17	57.0%	98.05
1959		81%	19%	20.0%	3.07	61.5%	105.77
1960		79%	21%	22.0%	2.99	65.7%	112.96
1961		77%	23%	24.0%	2.90	69.6%	119.64
1962		75%	25%	25.0%	2.81	70.3%	121.00
1963		75%	25%	25.0%	2.73	68.3%	117.47
1964		75%	25%	25.0%	2.65	66.3%	114.05
1965		75%	25%	25.5%	2.58	65.7%	112.94
1966	Active Flyash Pile	74%	26%	26.5%	2.50	66.3%	113.95
1967		73%	27%	27.5%	2.43	66.7%	114.81
1968		72%	28%	28.5%	2.36	67.2%	115.52
1969		71%	29%	29.5%	2.29	67.5%	116.09
1970		70%	30%	31.0%	2.22	68.9%	118.44
1971		68%	32%	33.0%	2.16	71.2%	122.41
1972		66%	34%	35.0%	2.09	73.3%	126.05
1973		64%	36%	37.0%	2.03	75.2%	129.37
1974		62%	38%	39.0%	1.97	77.0%	132.39
1975		60%	40%	41.0%	1.92	78.6%	135.12
1976		58%	42%	43.0%	1.86	80.0%	137.59
1977		56%	44%	45.0%	1.81	81.3%	139.79
1978		54%	46%	47.0%	1.75	82.4%	141.75
1979		52%	48%	49.0%	1.70	83.4%	143.48
1980		50%	50%	50.5%	1.65	83.5%	143.57
1981		49%	51%	51.5%	1.60	82.6%	142.14
1982		48%	52%	52.5%	1.56	81.8%	140.68
1983		47%	53%	53.5%	1.51	80.9%	139.19
1984		46%	54%	54.5%	1.47	80.0%	137.66
1985		45%	55%	55.5%	1.43	79.1%	136.10
1986		44%	56%	55.5%	1.38	76.8%	132.14
1987	SWRB	45%	55%	55.0%	1.34	73.9%	127.13
1988		45%	55%	54.0%	1.30	70.5%	121.19
1989	production ends	47%	53%	51.5%	1.27	65.2%	112.21
1990	alternate water supplies provided	50%	50%	49.0%	1.23	60.3%	103.65
1991	SWRB expansion	52%	48%	45.5%	1.19	54.3%	93.45
1992	RA No. 3, waste pits strmwtr cntrls	57%	43%	43.0%	1.16	49.8%	85.74
1993		57%	43%	43.0%	1.13	48.4%	83.24
1994		57%	43%	43.0%	1.09	47.0%	80.82
1995		57%	43%	39.0%	1.06	41.4%	71.17
1996	Public Water Supply installed	65%	35%	35.0%	1.03	36.1%	62.01
1997		65%	35%	32.5%	1.00	32.5%	55.90
1998	remedial action initiated	70%	30%	29.0%	0.97	28.2%	48.43
1999		72%	28%	27.0%	0.94	25.5%	43.77
2000		74%	26%	25.0%	0.92	22.9%	39.35
2001		76%	24%	23.0%	0.89	20.4%	35.15
2002		78%	22%	21.0%	0.86	18.1%	31.16
2003		80%	20%	19.0%	0.84	15.9%	27.37
2004		82%	18%	17.0%	0.81	13.8%	23.77
2005		84%	16%	15.0%	0.79	11.8%	20.37
2006		86%	14%	13.0%	0.77	10.0%	17.14
2007		88%	12%	11.0%	0.74	8.2%	14.08
2008		90%	10%	7.5%	0.72	5.4%	9.32
2009	remedial action complete	95%	5%	5.0%	0.70	3.5%	6.03

Total Discounted effective acre-years lost = 5287.02

Draft HEA Analysis for theGreat Miami Aquifer
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
1998	remedial action initiated	70%	71.0%	0.97	0.69
1999		72%	73.0%	0.94	0.69
2000		74%	75.0%	0.92	0.69
2001		76%	77.0%	0.89	0.68
2002		78%	79.0%	0.86	0.68
2003		80%	81.0%	0.84	0.68
2004		82%	83.0%	0.81	0.67
2005		84%	85.0%	0.79	0.67
2006		86%	87.0%	0.77	0.67
2007		88%	89.0%	0.74	0.66
2008		90%	92.5%	0.72	0.67
2009	remedial action complete	95%	95.0%	0.70	0.67
2010	to infinity	95%	95.0%	na	25.60

Total gain in discounted effective acre-years/acre = 33.72

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 5287.02

Present discounted gain in effective acre-years/acre (G) = 33.72

Acres of replacement habitat required for compensation (R, R=L/G) = 156.80

Total restoration acreage required = 328.80

Related Information

Total acres of Great Miami Aquifer contaminated above uranium MCL = 172

Acres of treatment for the primary restoration project = 172

Annual discount rate = 3.00%

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3.7 Great Miami River

The Great Miami River is the major water feature in the vicinity of the FEMP. It flows through several urban areas before joining the Ohio River. As expected, the Great Miami River receives point and nonpoint discharges from a variety of industrial, municipal, and agricultural sources. The HEA calculations for impacts to the Great Miami River were modified in that no primary restoration service gains were estimated and divided into the total loss in effective acre-years. Rather, the total interim loss was incorporated entirely into the on-property restoration acreages. The assumptions used in calculating the HEA worksheet are outlined below.

3.7.1 Assumptions

- For the purposes of calculating HEA, the total effected area of the Great Miami River was assumed to encompass 3.22 acres. This value is estimated from 2.97 acres of stream habitat and 0.25 acres of riparian habitat in the vicinity of the FEMP outfall line. The 2.97 acres of stream habitat were estimated from two sampling sites along the western shore of the Great Miami River that are surveyed by the University of Cincinnati as part of annual electrofishing surveys. The sampling sites are downstream of the FEMP outfall line (River Mile 24) and downstream of the confluence with Paddys Run (River Mile 19). The acreage estimate was obtained by taking the linear feet of each sample site and multiplying by 10 feet to estimate an area measurement.

- Service levels are estimated by assuming a 1% reduction for every 1000 kg of uranium released annually into the Great Miami River. Where actual records of annual discharge are not available, estimates were made based on historic trends.

- The 1993 service level is estimated at 91% based on an 8% reduction due to the removal of contaminated riprap in the vicinity of the FEMP outfall line. 0.25 acres of riparian habitat were impacted by the riprap removal. The percentage reduction is calculated by the ratio of impacted habitat to the total area (0.25/2.97, or 8%). The additional percent loss is due to the 1993 discharge of approximately 550 kg of uranium into the Great Miami River.

- Impacts are assumed to occur to the river until the year 2006, when all remedial actions at the FEMP will have been completed.

3.7.2 Results

The results of the HEA calculations indicate that 7.37 acres of restoration will be required to compensate for impacts to the Great Miami River. This restoration acreage will be added to the overall on-property restoration acreage in the NRRP.

Table 7

Draft HEA Analysis for the Great Miami River
Interim loss and resulting restoration acreage required

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	vg. Servic Loss/Acre	Effective Acres Lost
1952	kg U released from site: 11	100%	0%	0.0%	3.78	0.0%	0.00
1953	106	100%	0%	0.0%	3.67	0.0%	0.00
1954	347	100%	0%	0.5%	3.56	1.8%	0.06
1955	657	99%	1%	1.0%	3.46	3.5%	0.11
1956	1485	99%	1%	2.0%	3.36	6.7%	0.22
1957	2595	97%	3%	3.5%	3.26	11.4%	0.37
1958	3641	96%	4%	5.5%	3.17	17.4%	0.56
1959	6388	93%	7%	5.5%	3.07	16.9%	0.54
1960	4445	96%	4%	4.5%	2.99	13.4%	0.43
1961	5386	95%	5%	4.5%	2.90	13.0%	0.42
1962	3543	96%	4%	4.0%	2.81	11.3%	0.36
1963	4466	96%	4%	7.0%	2.73	19.1%	0.62
1964	10304	90%	10%	7.0%	2.65	18.6%	0.60
1965	3630	96%	4%	4.0%	2.58	10.3%	0.33
1966	3640	96%	4%	3.0%	2.50	7.5%	0.24
1967	2305	98%	2%	2.0%	2.43	4.9%	0.16
1968	1855	98%	2%	2.0%	2.36	4.7%	0.15
1969	2290	98%	2%	2.0%	2.29	4.6%	0.15
1970	1914	98%	2%	2.0%	2.22	4.4%	0.14
1971	1637	98%	2%	1.5%	2.16	3.2%	0.10
1972	1140	99%	1%	1.0%	2.09	2.1%	0.07
1973	1126	99%	1%	1.0%	2.03	2.0%	0.07
1974	1066	99%	1%	1.5%	1.97	3.0%	0.10
1975	1852	98%	2%	1.5%	1.92	2.9%	0.09
1976	875	99%	1%	1.0%	1.86	1.9%	0.06
1977	179	99%	1%	1.0%	1.81	1.8%	0.06
1978	965	99%	1%	1.0%	1.75	1.8%	0.06
1979	880	99%	1%	1.0%	1.70	1.7%	0.05
1980	1175	99%	1%	1.0%	1.65	1.7%	0.05
1981	685	99%	1%	1.0%	1.60	1.6%	0.05
1982	576	99%	1%	1.0%	1.56	1.6%	0.05
1983	755	99%	1%	1.0%	1.51	1.5%	0.05
1984	564	99%	1%	1.0%	1.47	1.5%	0.05
1985	1054	99%	1%	1.0%	1.43	1.4%	0.05
1986		99%	1%	1.0%	1.38	1.4%	0.04
1987		99%	1%	1.0%	1.34	1.3%	0.04
1988	SER results: ~860	99%	1%	1.0%	1.30	1.3%	0.04
1989	841	99%	1%	1.0%	1.27	1.3%	0.04
1990	786	99%	1%	1.0%	1.23	1.2%	0.04
1991		99%	1%	1.0%	1.19	1.2%	0.04
1992	~580	99%	1%	5.0%	1.16	5.8%	0.19
1993	~550, outfall line riprap upgrade	91%	9%	5.0%	1.13	5.6%	0.18
1994	461	99%	1%	1.0%	1.09	1.1%	0.04
1995	310	99%	1%	1.0%	1.06	1.1%	0.03
1996		99%	1%	1.0%	1.03	1.0%	0.03
1997		99%	1%	1.0%	1.00	1.0%	0.03
1998		99%	1%	1.0%	0.97	1.0%	0.03
1999		99%	1%	1.0%	0.94	0.9%	0.03
2000		99%	1%	1.0%	0.92	0.9%	0.03
2001		99%	1%	1.0%	0.89	0.9%	0.03
2002		99%	1%	1.0%	0.86	0.9%	0.03
2003		99%	1%	1.0%	0.84	0.8%	0.03
2004		99%	1%	0.7%	0.81	0.5%	0.02
2005		99%	1%	0.5%	0.79	0.4%	0.01
2006	remedial action complete	100%	0%	0.0%	0.77	0.0%	0.00

Total Discounted effective acre-years lost and restoration acreage required = 7.37

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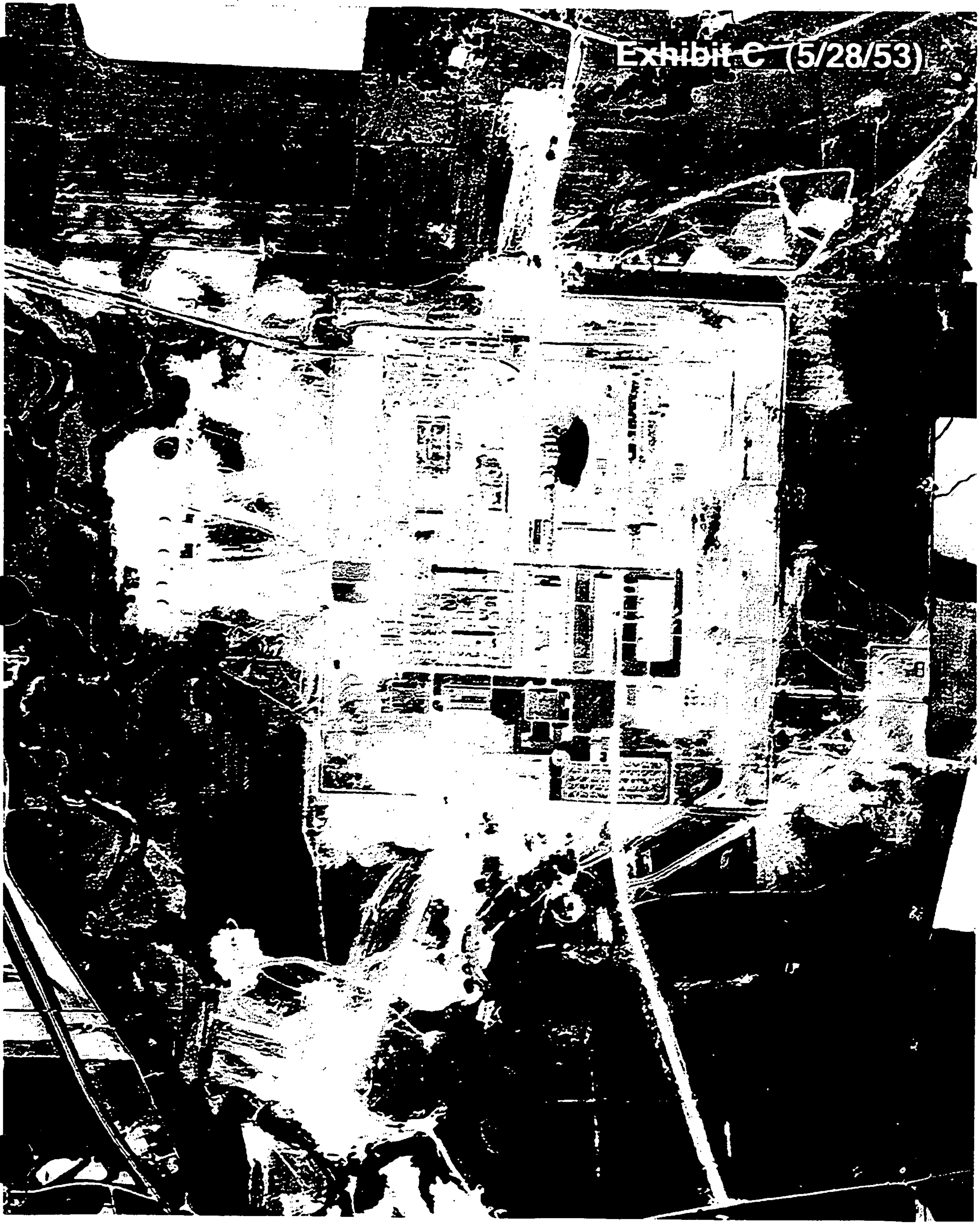
4.0 Conclusions

The results of the HEA worksheets for each area of the site add up to a total of approximately ~~852~~ 860 acres of restoration required to compensate for the impacts identified in the NRIA. The NRRP outlines the proposed projects to address this required restoration acreage. This number has the potential to increase or decrease as remediation proceeds depending on the actual amount of impact that occurs. Changes in the level of impacts will be identified during monitoring as outlined in the Natural Resource Impact Monitoring Plan (NRIMP). In case of an impact that varies from those anticipated in the NRIA, the HEA worksheets for specific areas of the site will be revised as appropriate. In addition, the NRRP will also be adjusted to provide a level of compensation commensurate with the acreage required by the HEA.


Exhibit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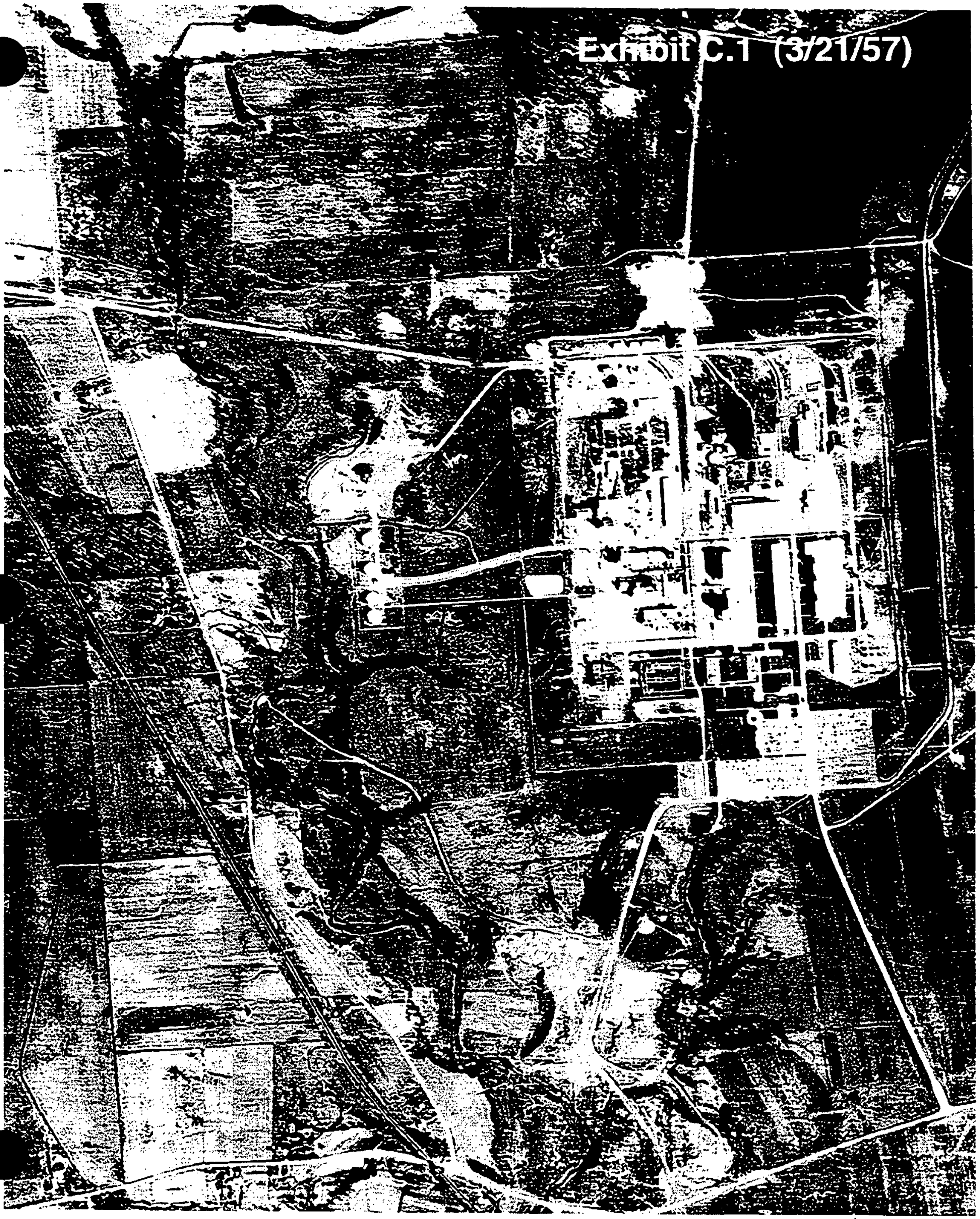
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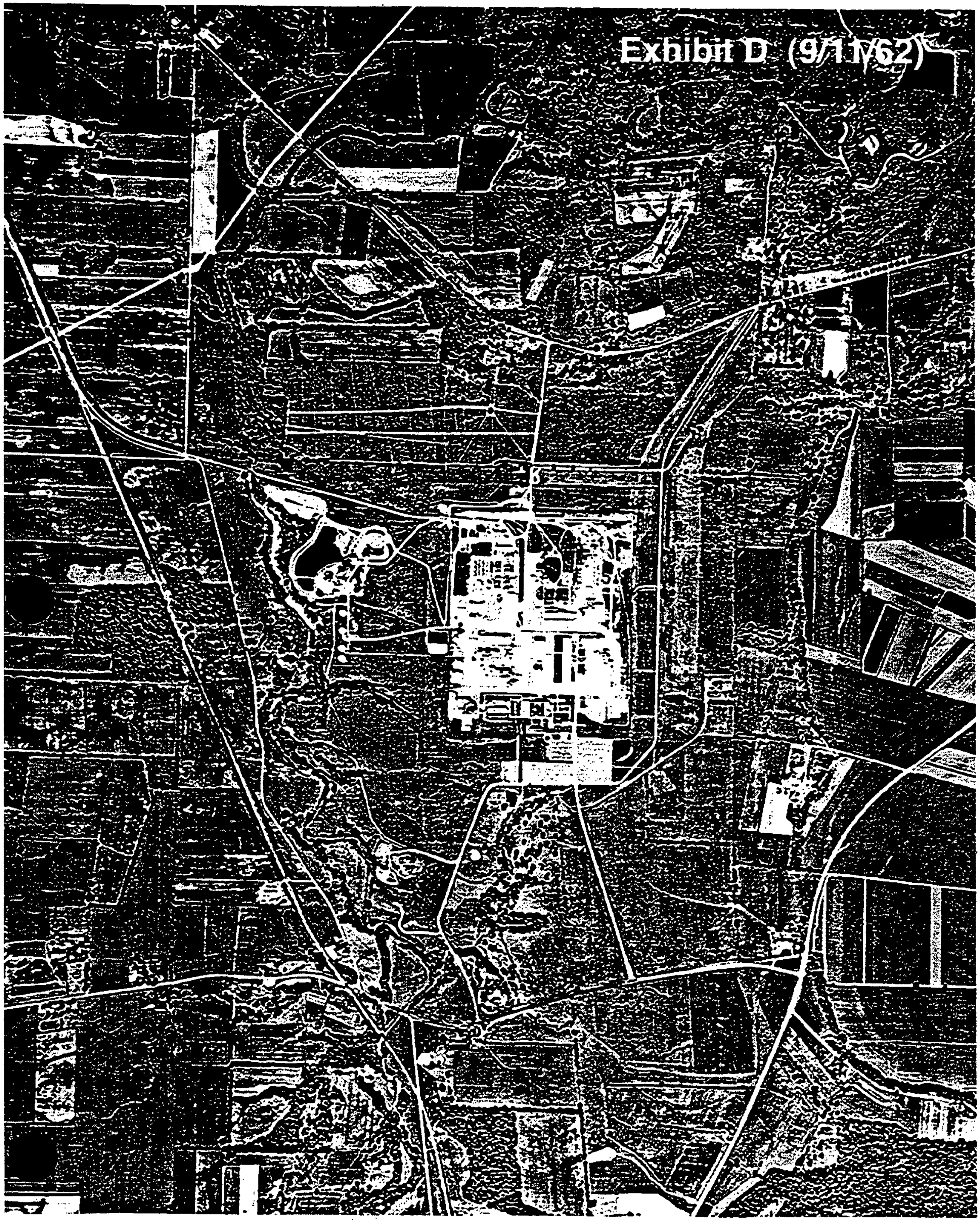
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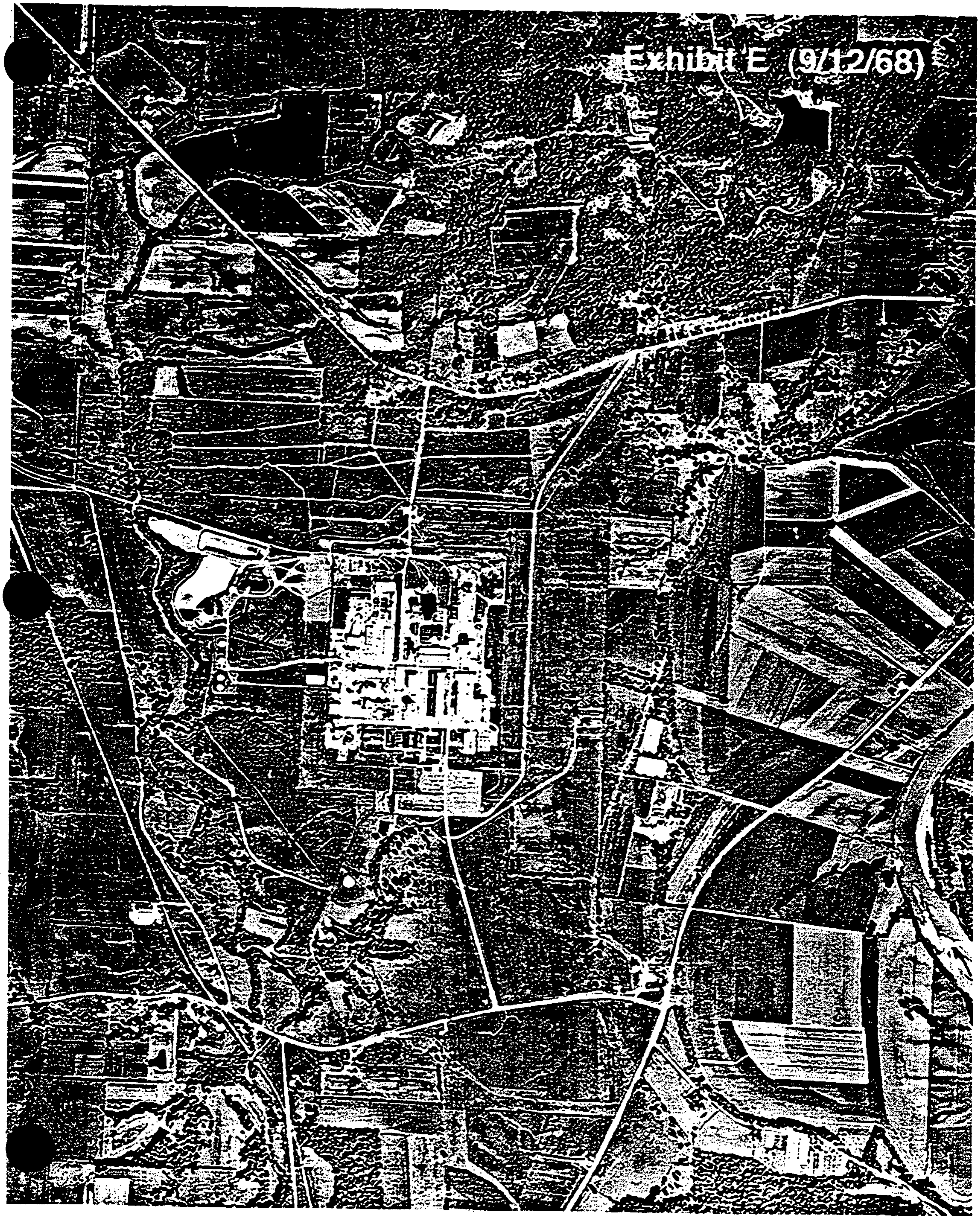
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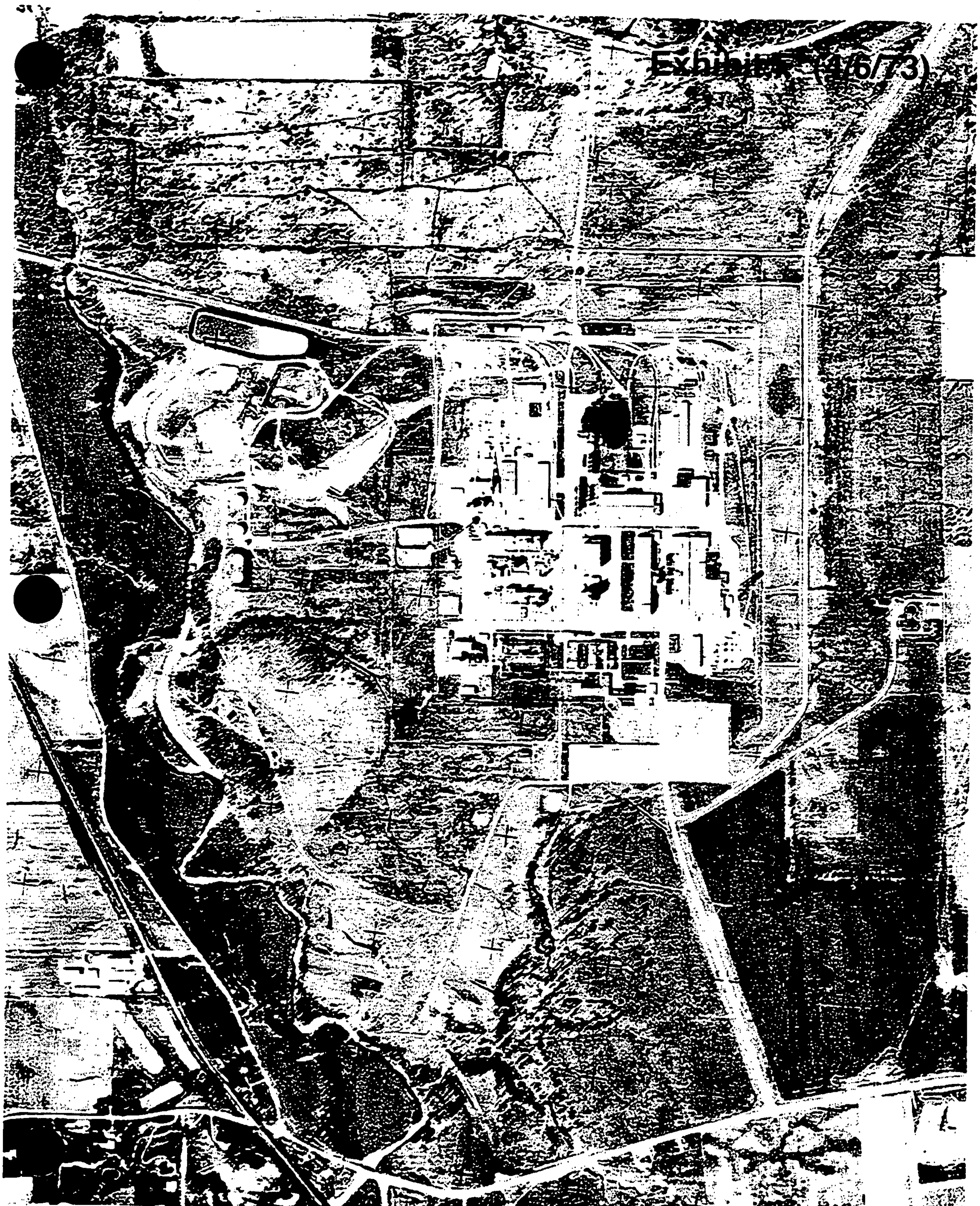
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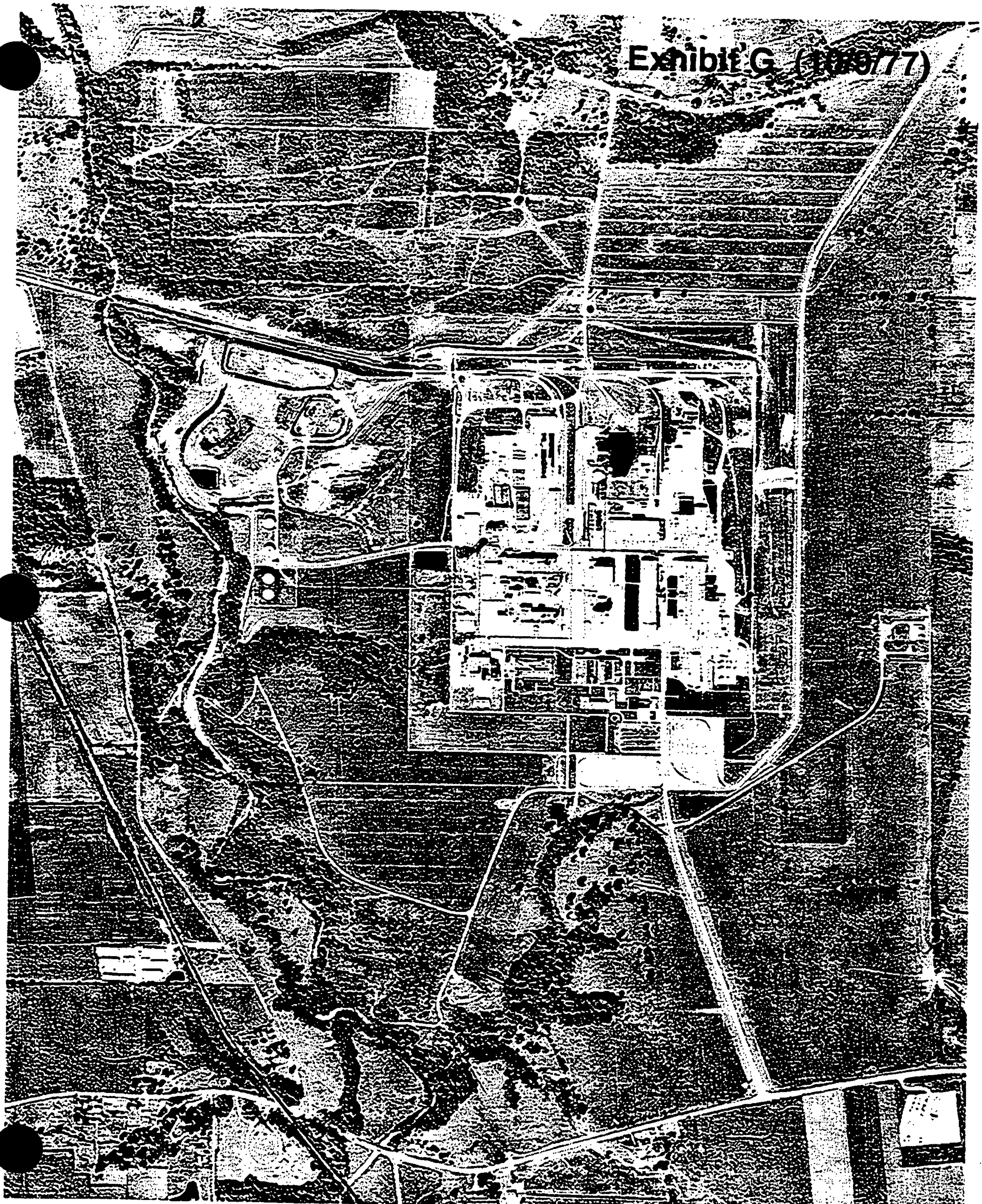
(4/6/73)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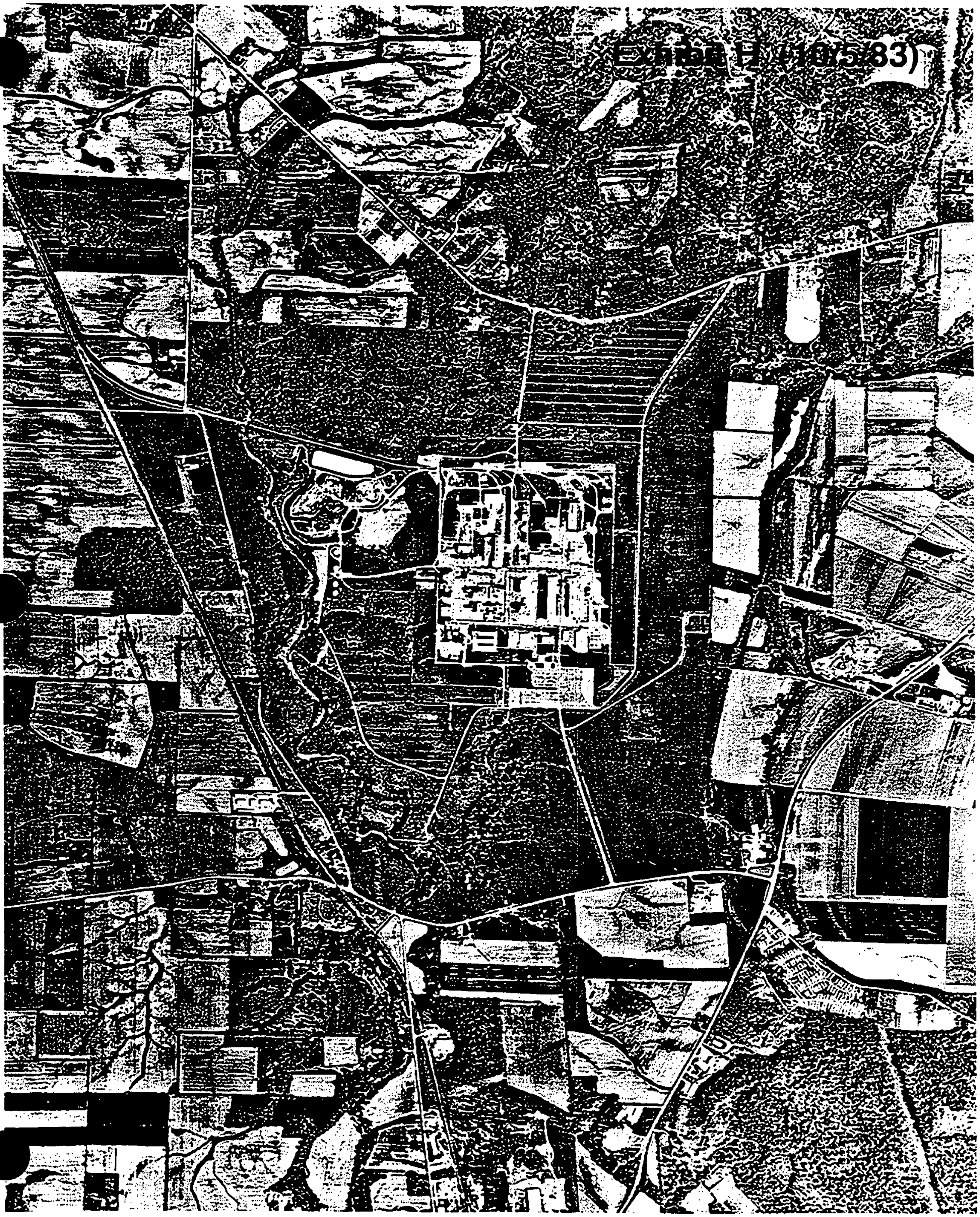
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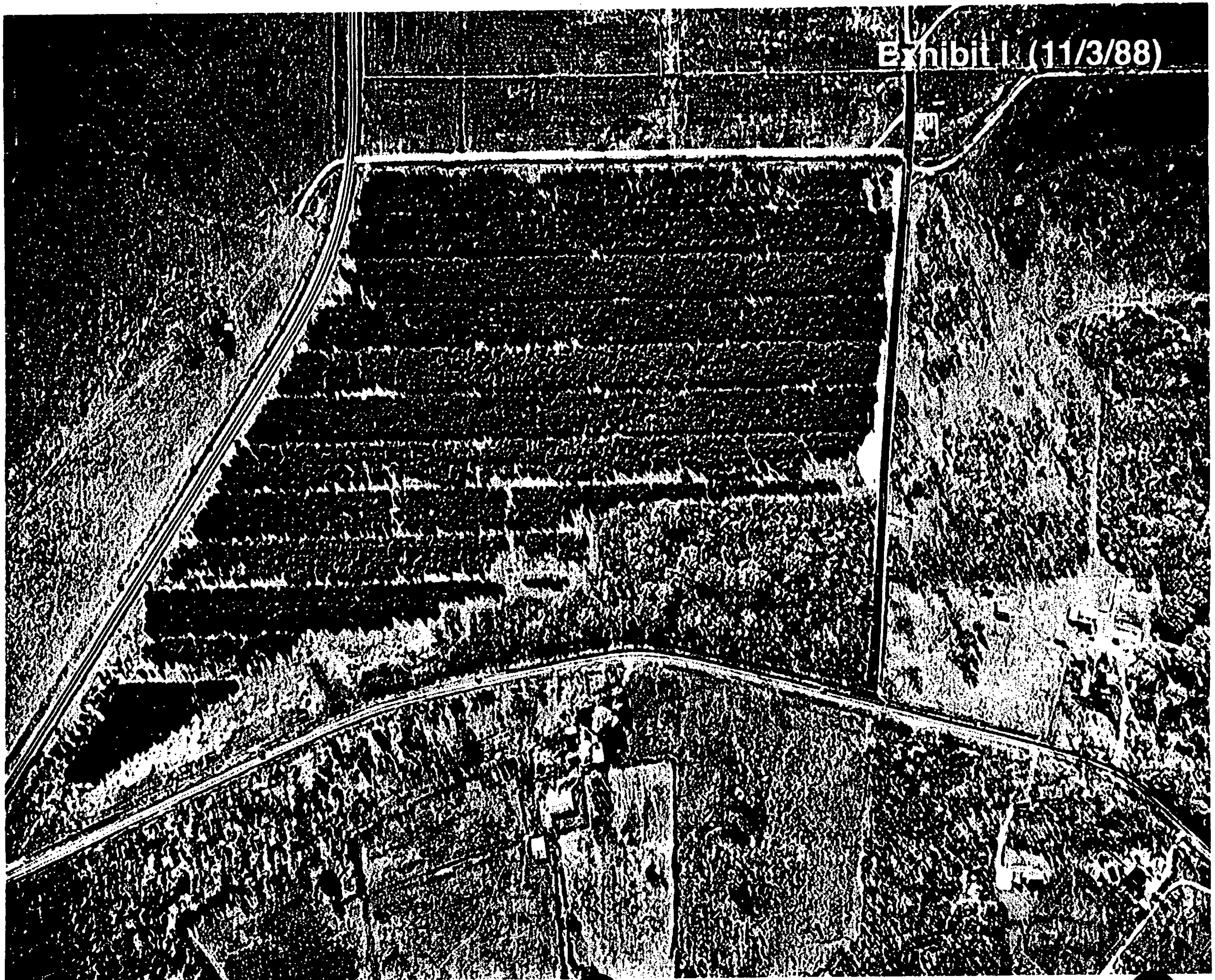
Exhibit I. (11/3/88)


Exhibit 1 (11/3/88)

ADDENDUM C

WATER AVAILABILITY STUDY

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WATER AVAILABILITY STUDY

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

PREPARED BY

BROWN & ROOT ENVIRONMENTAL
661 Andersen Drive
Pittsburgh, PA 15220

JULY 1, 1997

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FIGURES

EXECUTIVE SUMMARY

This study is intended to provide quantitative modeling results regarding the surface water routing for the four ponds under post-remediation conditions at Fernald Environmental Management Project (FEMP) site. The modeling results support the goal for natural resources restoration in the context of on-property open water/wetland habitats. As part of the site-wide restoration plan, four on-property open water areas are to be established in the former production area and its vicinity as a result of soil excavation activities. The integration of the ponds will provide open water areas for surface water habitats, and will provide sediment detention from activities such as remediation, construction, and excavation.

To ensure the engineering control and suitability of the ponds, storage routing modeling must be performed to assist understanding of the relationship of storage-stage-discharge of ponds. This engineering analysis is required to be analyzed under both normal conditions and extreme conditions. The normal conditions can be represented by considering the monthly average meteorological record, while the extreme conditions can be simulated by a storm event. The peak inflow rates generated by a storm event were modeled by using the TR55 method that is suitable for a small watershed. The characteristic storm typically considered in the TR55 method is a storm with 25-year return period and 24-hour duration.

Prior to the formulation of the routing model, the subbasin areas and drainage areas were first established. The storage routing model was then implemented secondly based on the conservation of mass, assuming that the rate of change of storage equals to the difference between the inflow and outflow. Water input to the ponds are rainfall and storm runoff. Outflow from the ponds are evaporation, infiltration loss through pond liner materials, and overflow from the weirs. The simulation time used was four years for normal conditions to reach an equilibrium state. In order for the model to be conservative for the extreme conditions, the initial storage of the ponds has incorporated the maximum storage volume predicted under normal conditions.

The routing modeling results indicated that the maximum and average depths of the ponds are constantly below the top edge of the ponds under both normal and extreme conditions. These results are based on allowing overflow when the pool level exceeds the designed overflow bottom elevation. Normally, the pool level in Pond 1 is the highest since it has a larger drainage area. Excess runoff from Pond 1 is allowed to be discharged to the Storm Sewer Outfall Ditch (SSOD). Excess water is also allowed to be drained from Pond 2 to Pond 4 through an open channel. The final outfall point for stormwater runoff routing through

Pond 1, Pond 3, and Pond 4 are the SSOD, which drains to Paddy's Run and eventually to the Great Miami River.

The maximum water depths estimated for the four ponds, when the peak inflow rates appear under the extreme conditions are approximately 19.1, 17.7, 14.1, and 25.5 feet respectively. At the same time, the average water depths estimated for the four ponds are 8.4, 10.7, 4.2, and 14.9 feet respectively. The corresponding maximum water surface acreage computed for the four ponds are 13.34, 14.0, 12.9, and 4.12 acres respectively. Also, the average water surface acreage computed for the four ponds are 13.03, 13.85, 12.0, and 4.02 acres respectively.

Based on the modeling results, it is suggested that an underground pipe be connected between Pond 1 and Pond 2. This connection will greatly improve the regulation of water storage between Pond 1 and Pond 2. This is because Pond 2 has a much larger capacity with approximately seven feet of freeboard under all conditions considered.

1.0 INTRODUCTION

This study is intended is to provide quantitative modeling results concerning the surface water routing for the four ponds under post-remediation conditions at Fernald Environmental Management Project (FEMP) site. The modeling results support the goal for natural resources restoration in the context of on-property open water/wetland habitats. These ponds are established as a result of soil remediation activities in the former production area and its vicinities within the FEMP site. The hydrologic conditions of ponds were modeled under normal climate conditions as well as storm event conditions. To achieve the goal of restoring natural resources, a comprehensive site-wide restoration plan is in the process of being implemented when excavation of contaminated soil at FEMP site is completed. As part of the restoration plan, four on-property ponds are to be established in the southern portion of the former production area. The integration of ponds will provide open water areas for surface water habitats, and will provide sediment detention from activities such as remediation, construction, and excavation.

1.1 SITE BACKGROUND

The U.S. Department of Energy's (DOE) FEMP site occupies 1,050 acres in rural southwestern Ohio, approximately 18 miles northwest of downtown Cincinnati, Ohio. The DOE's Fernald facility produced high-purity uranium metal products in support of the U.S. defense program from 1953 to 1989. Production was ceased in 1989, after the United States Environmental Protection Agency (USEPA) placed the sites on the National Priority List for remediation. Subsequently, the remedial efforts were initiated under the Comprehensive Environmental Response Compensation, and Liabilities Act (CERCLA).

The FEMP site is bounded by Paddys Run on the west, Willey Road to the south, and route 126 to the north. It is located at approximately 39°18' 06 " north latitude and 84°42' 30" west longitude. The site lies within the Great Miami River Drainage basin, with the Great Miami River flowing approximately 1.5 miles to the east.

For the remediation of contaminated soil in the shallow subsurface, it will be necessary to conduct site-wide soil excavation. This excavation plan will require the removal of approximately 20 feet of the contaminated soil delineated in the former production area and adjacent areas. The soils designated for remediation are mainly the gray clay at the base of the glacial overburden layer.

1.2 OBJECTIVES AND SCOPE

The primary purpose of the four on-property ponds is to restore the natural resources of surface water, and promote the land use for a natural park. To ensure the proper engineering control, storage routing modeling must be performed in assisting the understanding of the relationship of storage-stage-discharge of ponds. This engineering analysis is required for analyzing under both normal conditions and storm event conditions.

As indicated in the conceptual final land use, the developed park will be composed of a portion of open water surface areas, enhanced forest, and vegetated woodland adjacent to the open water areas (Figure 1-2). Based on the post-excavation site-wide grading map, the ponds will serve the purposes of runoff control through storage and routing the excess peak flow (Figure 1-1). The ponds will also provide open water space for surface water habitats. More specific objectives of the open water areas are:

- Controlling and storage of surface water runoff for the post-remediation conditions.
- Regulate the excess runoff during a storm event.
- Provide detention basins of sediment from soil remediation activities.
- Collecting the excess perched water near the former production area

1.3 OVERVIEW OF THE TECHNICAL PROCEDURES

The general technical steps for this pond modeling are briefly outlined as below:

- Investigation of the surface features for the post-excavation conditions.
- Delineation of the pond boundaries
- Delineation of outline of the pond water surface at 5-foot contour increments.
- Determination of subbasins that contribute surface runoff to the four pond areas.
- Estimation of drainage area for each individual pond.
- Determination of stage and storage relationship.

Under Normal Conditions

- Estimation of monthly mean rainfall depth.
- Estimation of monthly mean stormwater runoff depth.
- Estimation of monthly mean infiltration rates.
- Estimation of monthly mean evaporation rates.
- Assembling the reservoir routing model based on one month interval.

- Implementing the reservoir routing model with the four ponds linked together.

Under Extreme Conditions

Technical Release 55 (TR55) method was used to calculate the peak rate of discharge and hydrographs for floodwater ponds at FEMP site.

- Implementation of a conceptual model for subbasins and channels in relation to the watershed drainage path.
- Computation of peak inflow to the ponds generated by a 25-year frequency and 24-hour duration storm event.
- Generation of tabular hydrograph.
- Assembling the reservoir routing model based on six minutes time interval.
- Designing the hydraulic connections (discharging channel, and overflow weirs) between the ponds.
- Implementing the flood routing model with the four ponds linked together.
- Sizing of the discharging channel.
- Determination of the adequacy in hydraulic design and planning based on the modeling results.

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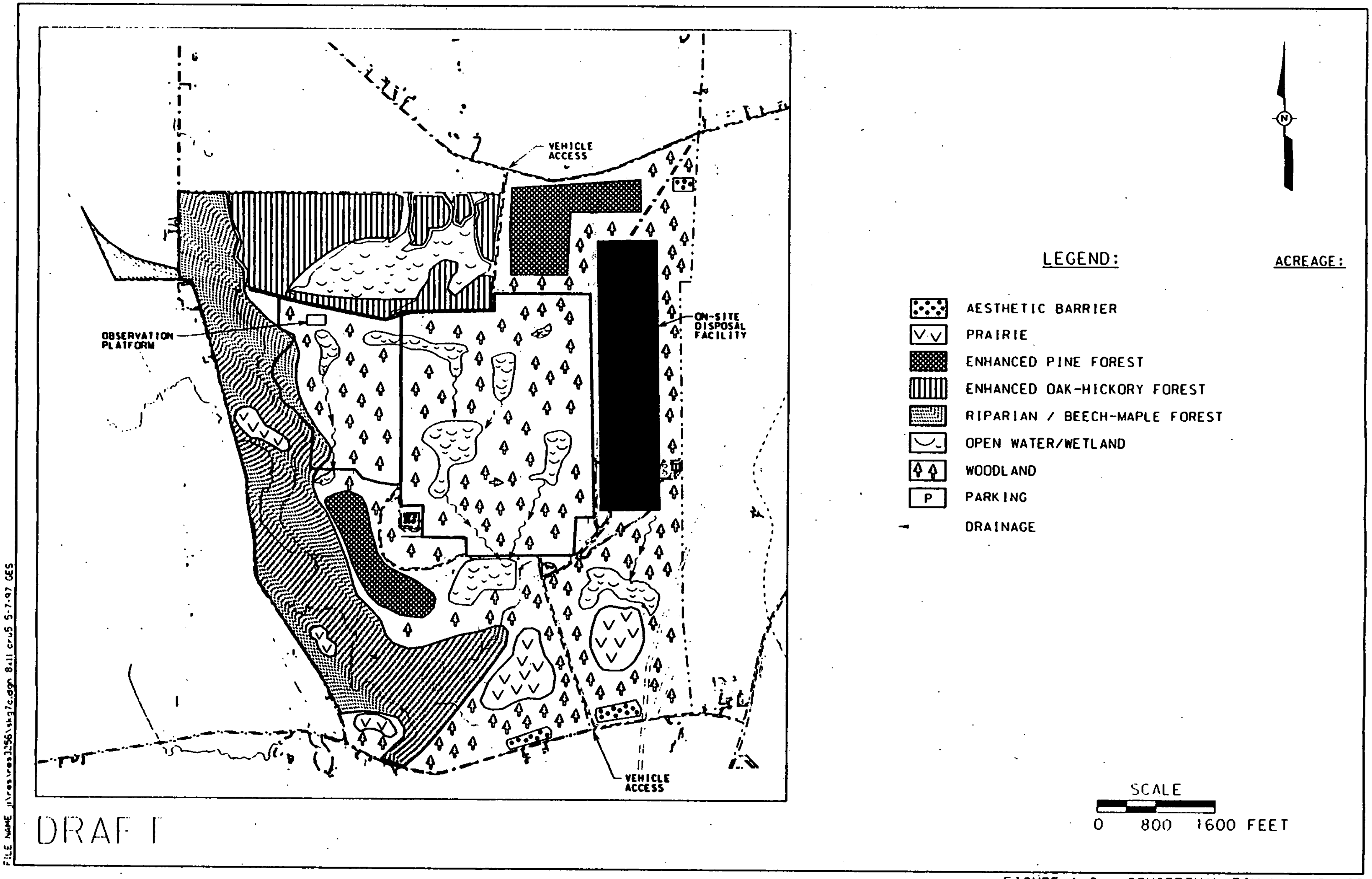

FIGURE 1-2. CONCEPTUAL FINAL LAND-USE

2.0 CONCEPTUAL MODEL DEVELOPMENT

This section presents the conceptual model and technical approach used for developing pond routing, in relation to pond storage and pond stage.

2.1 SURFACE FEATURES AT POST-EXCAVATION CONDITIONS

In developing the pond routing model, the post-remediation site surface conditions are used. Figure 1-1 presents the projected post-excavation topographic map. The existing topography is mainly level in the former production area with the remainder of the site gently sloping throughout. The elevations range from a high point of approximately 700 feet MSL within the northeastern reaches of the site, to a low point of 550 feet MSL within the Paddys Run corridor at the southwestern corner of the site. Surface slopes associated with on-site stream channels are severe.

For the projected post-excavation conditions, Pond 1 is established in the northeast of FEMP, and also east of the former production area. Pond 2 is developed west of Pond 1. Pond 3 is at the south side of FEMP, and was designated as the soil borrow area for the construction of On Site Disposal Facility (OSDF) and other structures. Pond 3 lies on a steep hills, therefore, its storage capacity is quite limited. However, Pond 3 is for temporary runoff storage purpose. Stormwater in Pond 3 can be freely overflowed to the SSOD. Pond 4 is also designated as a stormwater retention pond, and is west of Pond 3.

Soil Excavation Zones

The proposed soil excavation areas are mainly within the on-property areas, excluding the northern portion of the FEMP site, these areas include:

- The Former Production Area
- Waste Storage/management Areas
- Existing Stockpiles
- Shallow excavation of Impacted, On-property Areas
- Pipeline excavation outside of the Former Production Area

In addition to the soil excavation, OSDF will be constructed at the eastern border for containing the processed low-level radionuclide waste. Construction of the OSDF will require some road and traffic changes. Hence, only the existing topography in the northern portion of the FEMP site remains unchanged since this area is not designated in the boundary of soil remediation.

The excavation of the soil during remediation will change the runoff characteristics of some of the remediated areas. As indicated in figure 1-1, the soil excavation activities occur mainly in the former production area and its vicinities. The change of runoff characteristics in this area are a result of the remediation activities. Prior to the remediation, much of the production area is covered with buildings and pavement. During remediation these structures will be removed, followed by soil excavation, interim grading, establishment of vegetation, and other necessary restoration requirements. Therefore, the surface features at the post-remediation condition will be altered, when compared to the current conditions. The post-remediation site surface conditions are used for reflecting the changes such as runoff curve numbers, and drainage paths.

Subsurface Features in the Excavation Zones

The subsurface soils designated for remediation at the vicinity of FEMP consist of mainly impermeable gray clay at the base of the glacial overburden. Within this shallow excavation zone, the perched groundwater table elevation is generally high. It ranges from 574 to 576 feet in the area of Pond 1 and 2, and is approximately 570 feet in the vicinity of Pond 4 (retention pond) and Pond 3 (borrow area). The contaminated perched groundwater is located in the weathered portion of the overburden which contains fractures.

2.2 SUBBASIN AND DRAINAGE AREAS

The FEMP property can be divided into several subbasins based on drainage divides to allow for the analysis of separate areas of the FEMP containing different surface conditions and stormwater drainage systems. As shown in Figures 1-1, the drainage basin that contributes to each individual pond consists of multiple subbasins. The physical configuration of these subbasins are important in the estimation of runoff volume as well as the routing of inflow hydrograph. Since the configuration and location of the subbasins will directly affect the time of concentration and also the travel time, and subsequently determine the peak inflow rates for a storm event.

Table 2-1 presents the areas of the subbasins that contribute runoff to each individual pond. The total drainage area is also calculated in Table 2-1. As indicated in Table 2-1, the drainage area of Pond 1 consists of subbasins A, B, O, and L. The drainage area of Pond 2 is composed of subbasins N and M. The drainage area of Pond 3 encompasses subbasins C, E, F, and H. Pond 3 will collect runoff generated from the east portion of the OSDF (subbasin C) along with runoff from adjacent subbasin areas E and F, and finally drains through a culvert pipe to Pond 3. Runoff collected in subbasins K and J discharges to

Pond 4. Based on the post-excavation topographic map, the runoff collected from subbasins D, I, and G, which are located south of the OSDF, drains to SSOD.

The subbasin configurations in the OSDF area that are referred to in this study compared the peak discharge for pre-development conditions with the post-development conditions (Parsons, 1997). As stated in this study, a rerouting of drainage from the north and west areas of the OSDF draining into the OU1 Railyard channels has been considered.

2.3 STAGE AND STORAGE RELATIONSHIP

In general, the stage-storage relationship depends on the local topography at the site of the storage structures. At the FEMP site, the stage-storage relationship was derived as a discrete function (i.e. a set of points). The water surface areas within contour lines of the site can be plannimetered with five feet contours. Thus, the storage in a depth increment of five feet can be calculated by the product of the average area and the depth increment. Then, the total volume of storage is the summation of all the storage increments. The data presented in Table 2-2 were used to generate the stage-storage relationship for the routing modeling. Figure 2-2 presents the surface water area at stages for every five feet of increment of elevation. Figure 2-3 presents the stage-storage relationship of the four ponds. As indicated in Figure 2-3, Pond 2 has the highest storage, while Pond 3 has the lowest storage when compared at the same stage among the four ponds.

2.4 CONTROLLING FACTORS

The peak inflow rates and the maximum depths of the ponds are controlled by factors such as meteorological data, hydrological parameters as well as the surface features and subsurface soil stratum properties of the watersheds. These three major controlling factors are summarized in this section.

<u>Meteorological data</u>

The Meteorological data that affect the modeling results are:

- Monthly mean rainfall depth under the normal conditions
- Rainfall depth from a 25-year and 24-hour storm, and storm type under extreme conditions
- Air and water surface Temperature that will affect the saturated vapor pressure
- Relative humidity
- Wind speed
- Percentage of possible sunshine
- Net radiation

Hydrological data

The hydrological data that affect the modeling results are:

- Subbasin configuration in the watershed.
- Natural drainage channel length and size.
- Vegetation cover conditions upstream of the ponds
- Curve number corresponding to site soil group
- Drainage path slope.
- Time of concentration

Surface and subsurface features

The surface and subsurface features that affect the modeling results are:

- Final site-wide grading features.
- Thickness of pond liner
- Hydraulic conductivity of pond liner materials.
- Stage-storage relationship of individual pond.

2.5 STORAGE ROUTING MODEL

When planning pond development conditions, the routing process considerations take precedence. Storage routing refers to the process of estimating the passage of a storm or flood hydrograph through a pond or reservoir. The routing model is based on conservation of mass, which assumes that the rates of change of storage equals to the difference between the inflow and outflow. In comparison to other hydrological problems, storage routing is relatively complex. There are a number of variables involved, including :

- Input hydrograph (monthly mean rainfall and runoff depth)
- Output hydrograph (monthly mean pond evaporation and leakage from the pond liner)
- The stage-storage volume relationship
- The storage-water surface area relationship
- The stage-discharge relationship
- The designed peak discharge rates allowed through the pond

The drainage area is determined from the topographic map. It is assumed that the change of pond area will not change the drainage area for the routing process. The detailed storage routing equations are presented in Section 3.0.

2.6 POND INFLOW MODEL

As shown in Figure 2-1, the inflow term consists of two terms: runoff from the drainage area and rainfall directly into the pond. The monthly mean rainfall depth and runoff depth were used in the calculation under the normal conditions. The peak inflow rates were estimated using the TR55 method for extreme conditions. A brief overview of the TR55 method is provided in Section 5.0.

2.6.1 Monthly Average Rainfall and Runoff

The monthly mean precipitation was taken from database of National Oceanic and Atmospheric Administration (NOAA) (NOAA, 1986). The data are statistics from hourly precipitation data for Cincinnati, Ohio. The monthly runoff was calculated by using Hydrologic Evaluation of Landfill Performance (HELP) model based on the monthly mean precipitation data from NOAA. In HELP calculations, it is assumed that the ground surface will be compacted during the interim grading operation. Appendix A presents the monthly runoff depth calculations (HELP model).

2.7 POND OUTFLOW MODEL

The outflow components considered in the model were evaporation from the open water surface, infiltration loss from the pond liner materials, and overflow rates from the weirs when the stage exceeds the overflow bottom elevation (Figure 2-1).

2.7.1 Monthly Evaporation Model

The evaporation rate was estimated using Penman equation based on meteorological data from climate station within the study region, since direct evaporation data is not available. The Penman equation was developed for estimating evaporation from open water surface (McCUEN, 1989). In Penman's model, the following parameters are considered: air and water surface temperature, relative humidity, saturated vapor pressure, wind velocity, amount of radiation absorbed, outward flow of long-wave radiation, percent of possible sunshine etc. The detailed evaporation model equations are presented in Section 3.0.

2.7.2 Monthly Infiltration Model

The amount of infiltration through the pond liner material has incorporated the data presented in the infiltration zone model in the Feasibility Study Report (FS Report) (DOE, 1995). Based on Figures 2-4 and 2-5 originally presented in Appendix F of FS, bottom liner material is mainly the gray clay located at the base of the glacial overburden layer. Part of the Pond 1 liner materials consist of the unsaturated Great Miami Aquifer material. The gray clay is a clay-rich glacial till deposit, with an average porosity of 0.20. The reported hydraulic conductivity for gray clay is 7.23×10^{-7} cm/sec. The thickness of the liner was assumed to be 3 feet. The infiltration rates were estimated by Darcy's Law , which states that the infiltrated velocity is the product of the hydraulic conductivity of the pond liner and the vertical gradient of water depth inside the pond through the bottom liner. The infiltration equation is presented in Section 3.0.

2.8 POND LINER MATERIAL

As indicated in figures 2-4 and 2-5, the soil excavation in the Pond 2 area is in Infiltration Zone V, and will reach the formation of gray clay layer near the bottom of the overburden layer. This means the liner material for Pond 2 will be a natural gray clay material with a permeability of about 10^{-7} cm/sec. However, the soil excavation in the pond 1 area is in Infiltration Zone II & III, which reaches the unsaturated Great Miami Aquifer. The unsaturated Great Miami Aquifer is generally sandy material with a permeability range 10^{-2} to 10^{-3} cm/sec. Therefore, the liner material for Pond 1 requires replacement with either a lower permeability clay soil or a synthetic liner. Replacing the sandy soil will facilitate the minimum leakage of water through the liner materials.

2.9 HYDRAULIC CONNECTION PLAN

The hydraulic connections are necessary for regulating the storage in the ponds and to maintain open water space for surface water habitats. This design plan utilizes outlet facilities such as weirs and open channels for the conveyance of water between ponds or discharging to SSOD. In the hydraulic connection plan, excessive water from Pond 1 can be drained through an open channel to SSOD. Excessive water from Pond 2 will first be conveyed through an open channel to Pond 4 (retention pond), and then either store in Pond 4 or overflow to SSOD when the pool level in Pond 4 exceeds the weir bottom elevation. The excessive water in Pond 3 will simply overflow through a weir to SSOD.

2.10 POND DAILY OVERFLOW AND OUTFLOW DISCHARGE

It is assumed that overflow will take place in a pond when the surface water elevation in the pond is higher than a certain elevation (pond overflow elevation). Therefore, in the routing process, if the pond surface water is higher than the pond overflow elevation, the pond water will overflow until the pond surface water is just at or below the pond overflow elevation. Also, the daily overflow rate was estimated by dividing the total amount of overflow in a month by 30 days.

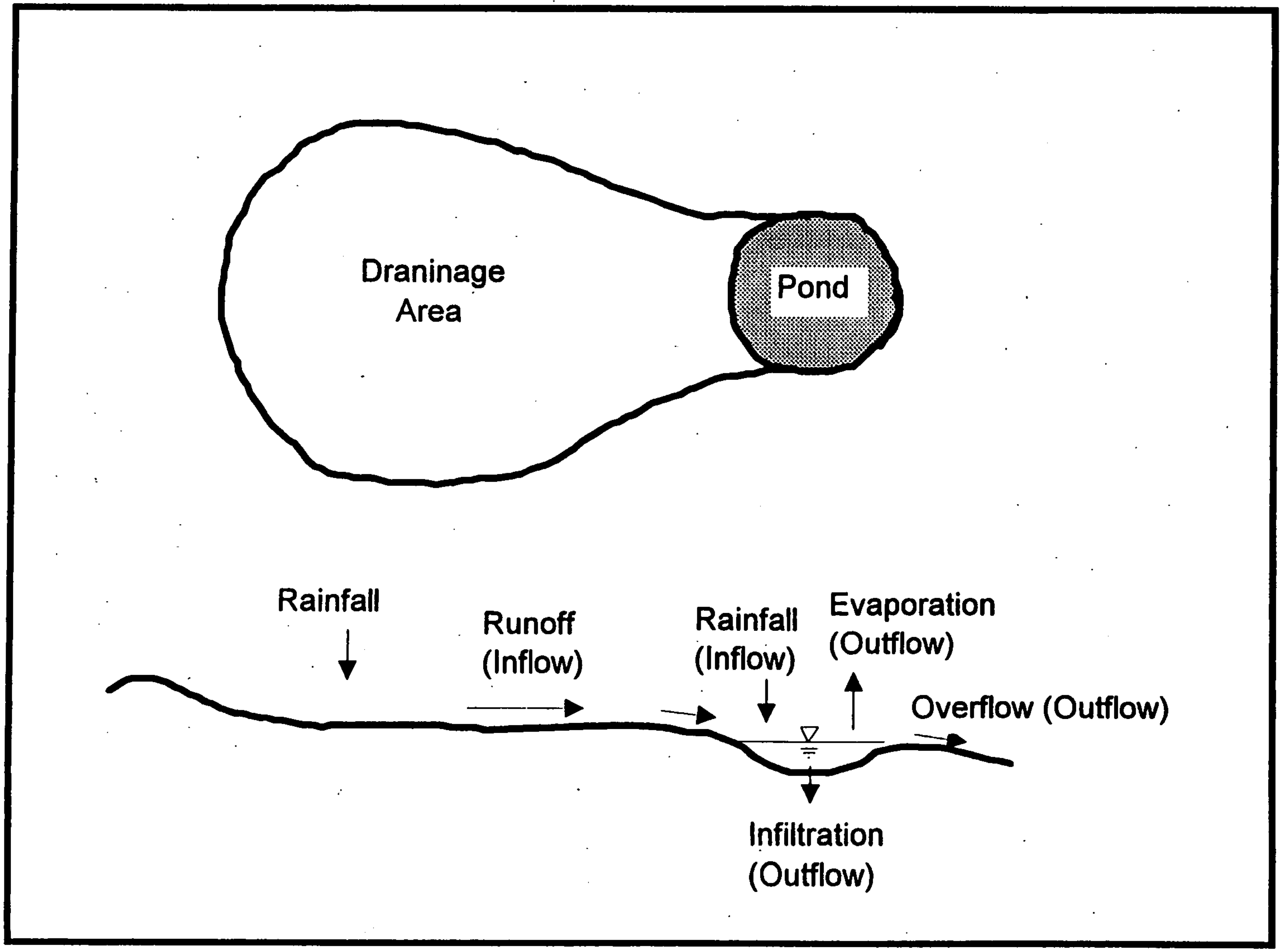

Figure 2-1 Conceptual Pond Routing Model

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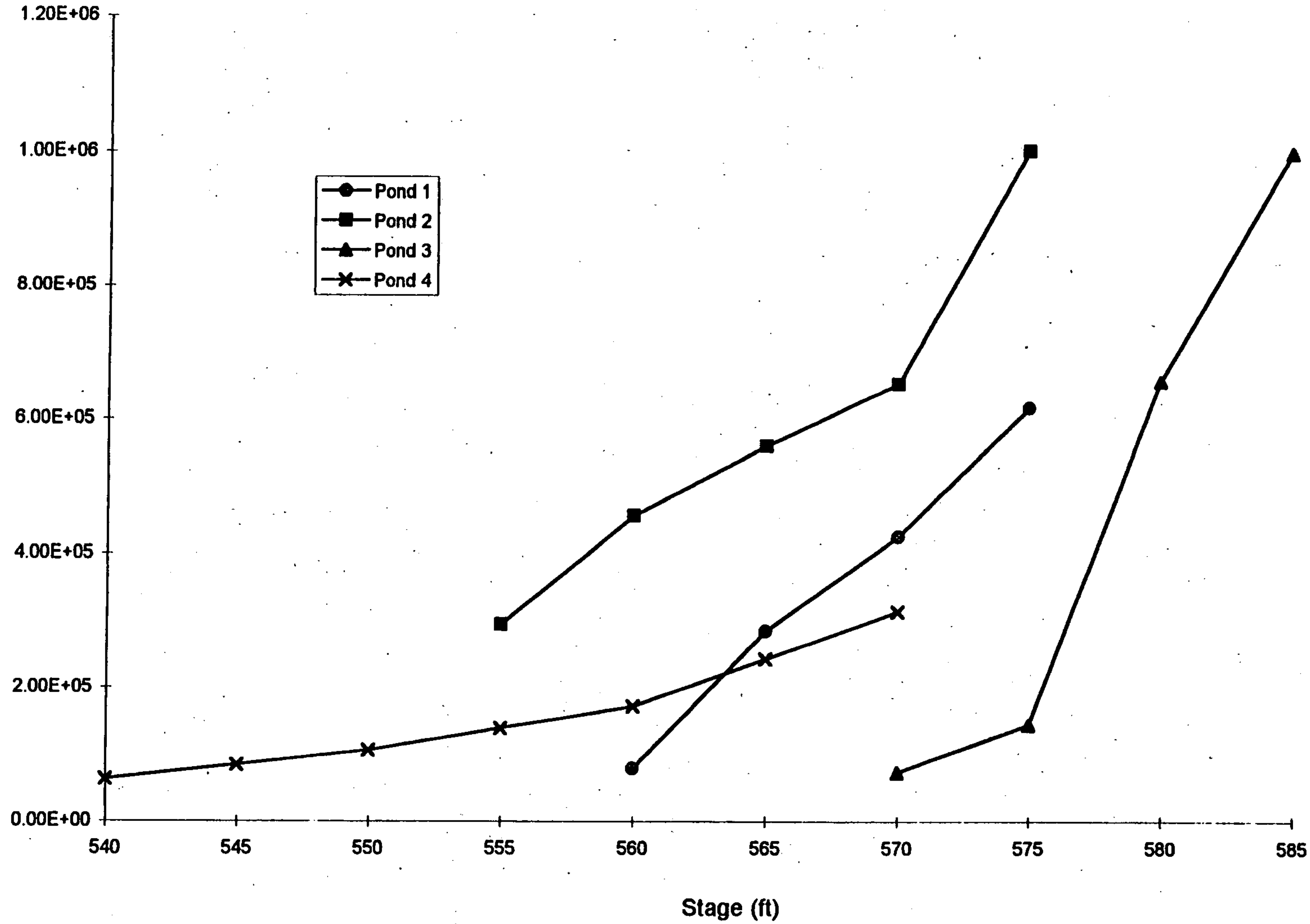

Figure 2-2 Stage and Water Surface Area Relationships

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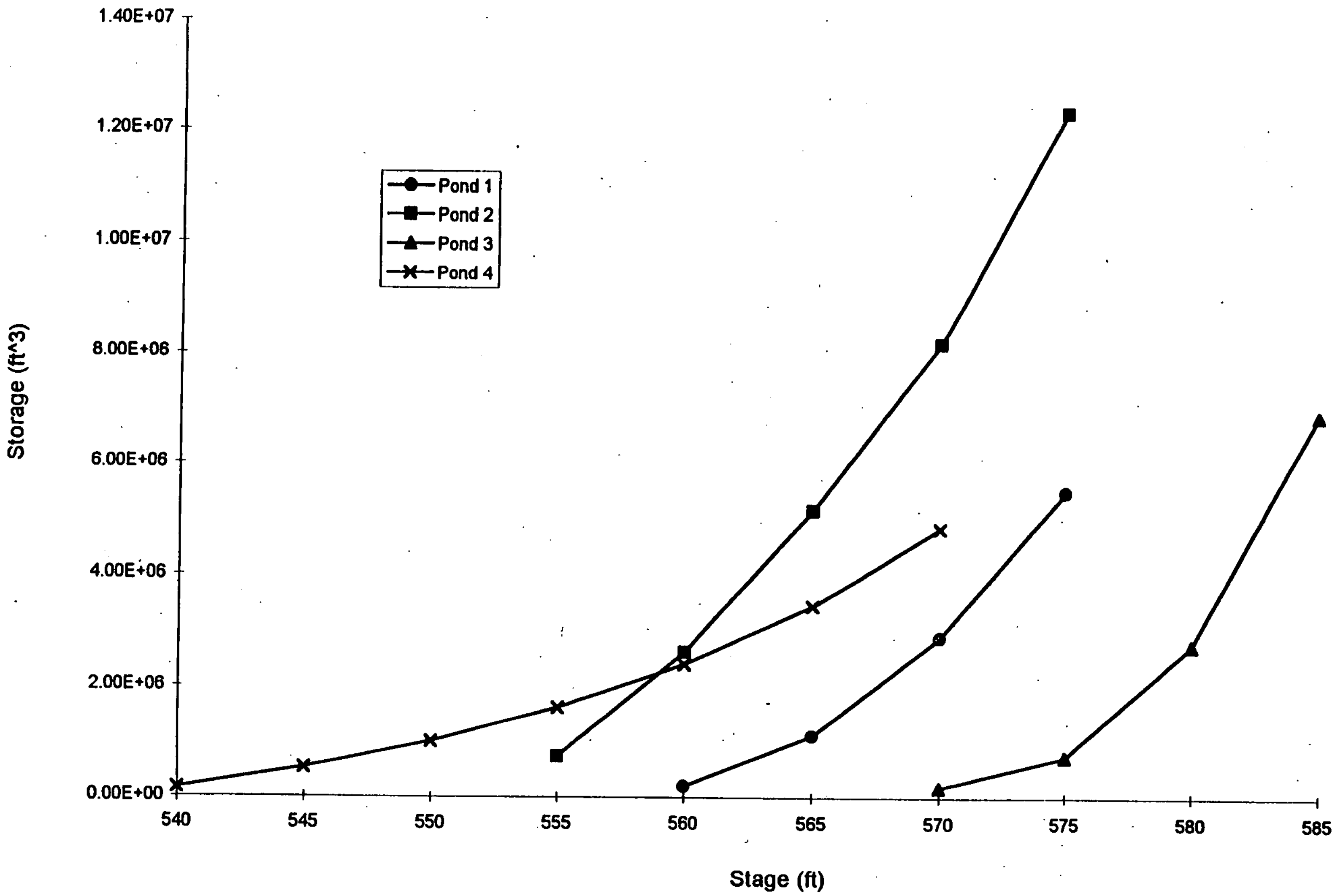
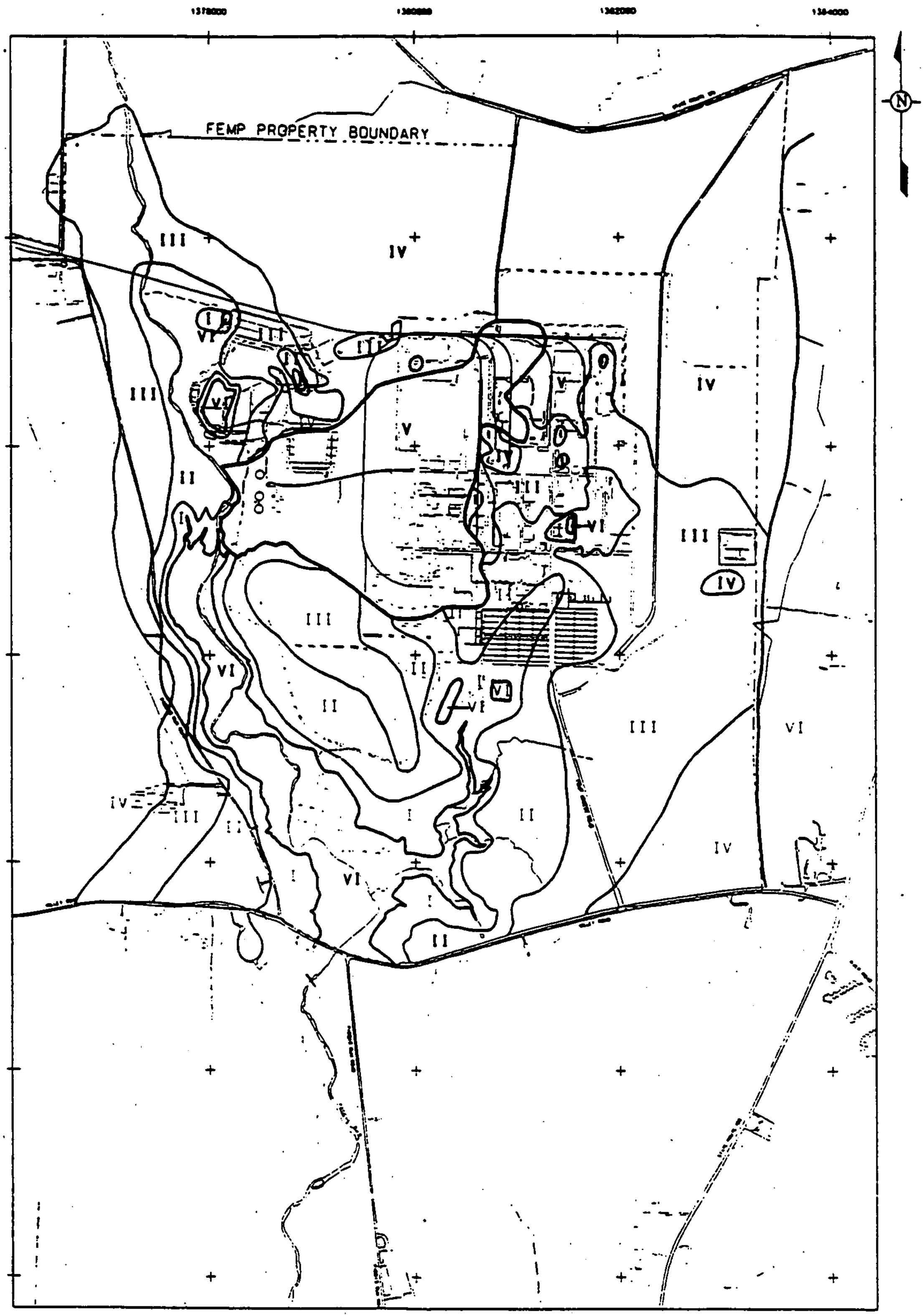


Figure 2-3 Stage and Storage Relationships



LEGEND:

ZONE		ZONE	
I	0-5' GRAY CLAY	IV	> 20' GRAY CLAY
II	5-10' GRAY CLAY	V	CONCEPTUAL SAND ZONE
III	10-20' GRAY CLAY	VI	NO GRAY CLAY

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FIGURE 2-4 INFILTRATION ZONES

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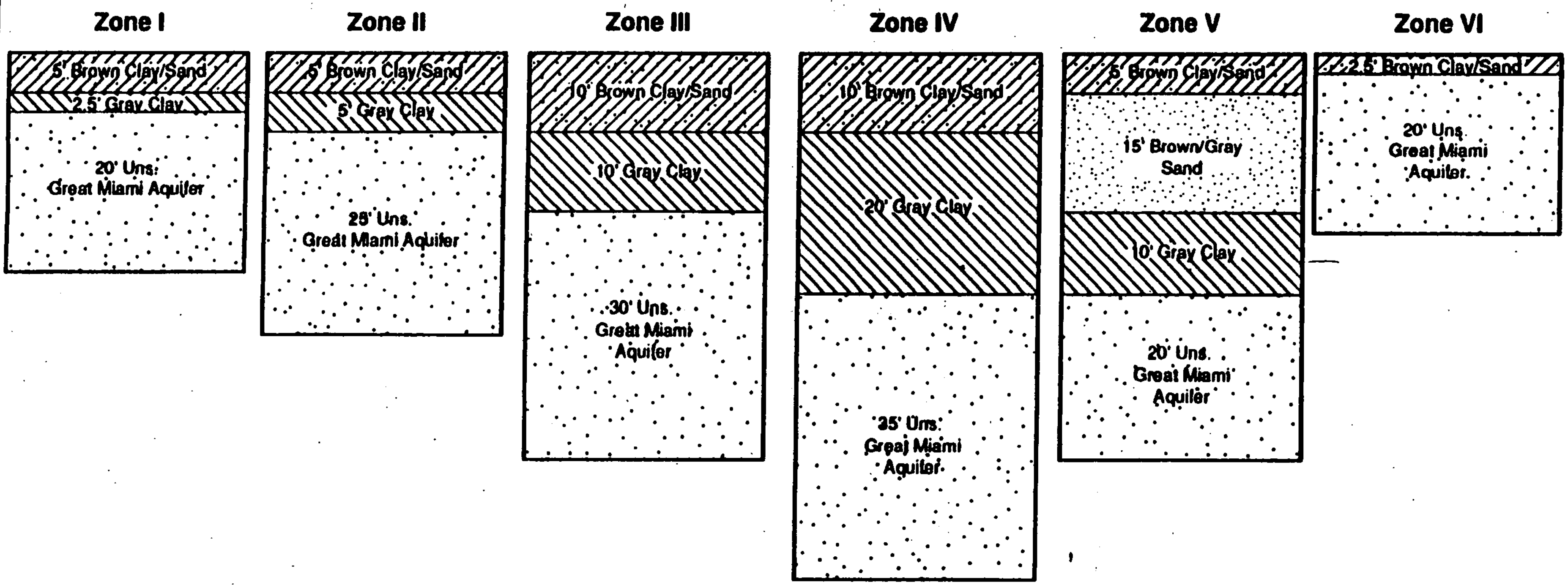

FORMATION	Kv (cm/sec)	POROSITY	DATA SOURCE
Gray Clay	7.23E -07	0.20	Kv from GO/UGMAS model calibration, ≈ 0.4 of geometric mean of slug test results
Brown/Gray Sand	1.10E -04	0.30	Harmonic mean of Kh from slug tests divided by 10
Brown Clay/Sand	7.04E -05	0.30	Harmonic mean of Kh from slug tests
Uns. GMA	1.59E -02	0.30	Kv from SWIFT Model Calibration

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FIGURE 2- 5 GENERALIZED CROSS SECTIONS

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TABLE 2-1
POND SUBBASIN AREAS AND DRAINAGE AREAS
FEMP - POST EXCAVATION CONDITION

	Subbasin			**Drainage Area**
	Subareas	ft^2	acres	acres
POND 1 (Northeast of FEMP)	A B O L	1150200 310500 2236500 1853100	26.4 7.1 51.3 42.5	127.4
POND 2 (Northwest of FEMP)	N M	2255400 2498400	51.8 57.4	109.1
POND 3 (Southeast of FEMP)	C E F H	1588500 311850 1003500 1624500	36.5 7.2 23.0 37.3	104.0
POND 4 Retention Pond	K J	378000 1768500	8.7 40.6	49.3
		Total Drainage Area for Pond		389.8

Note: Based on the post-excavation topographic map, the runoff collected from subbasins D, I, and G that are located south of the OSDF drains to SSOD.

TABLE 2-2

POND WATER SURFACE AREA AT DIFFERENT STAGES

Surface Elevation (ft) / Pond Surface Area (ft^2) / Pond	540	550	555	560	565	570	575	580	585	Pond Drainage Area (ft^2)
POND 1 (southeast side)				7.88E+04	2.85E+05	4.25E+05	6.17E+05			5.55E+08
POND 2 (south side)			2.94E+05	4.56E+05	5.59E+05	6.54E+05	1.00E+06			4.75E+06
POND 3 (south end)						7.32E+04	1.45E+05	6.58E+05	9.99E+05	4.53E+06
POND 4 (Retention POND)	6.30E+04	1.06E+05	1.39E+05	1.72E+05	2.43E+05	3.14E+05				2.15E+06

Note: 1 arce = 43560 ft^2

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FIG

TABLE 2-3

STAGE AND STORAGE RELATIONSHIPS

Surface Elevation (ft) / Pond Storage (ft^3) / Pond	540	550	555	560	565	570	575	580	585
POND 1 (southeast side)				1.97E+05	1.11E+06	2.88E+06	5.49E+06		
POND 2 (south side)			7.36E+05	2.61E+06	5.15E+06	8.18E+06	1.23E+07		
POND 3 (south end)						1.83E+05	7.28E+05	2.74E+06	6.88E+06
POND 4 (Retention POND)	1.58E+05	1.00E+06	1.61E+06	2.39E+06	3.43E+06	4.82E+06			

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Pond1-4o

Ch[illegible]d by:
Date :

TABLE 2-4
MONTHLY AVERAGE EVAPORATION RATES
POND ROUTING MODELING - FEMP

Input parameters

Sigma = 1.2E-07
Latitude = N 39.1 °
Reflection
Coeff r = 0.12
Empirical r (0.05-0.12)

Psychrometric Const.
(alpha) = 0.485 mm Hg/°C
Delta = $(e_o - e_s^*)/(To-Ta)$

Month	Temp °F	Temp °C	Temp T	Relative Humidity R_h %	Saturation Vapor Pressure e_s mm Hg (1)	Actual Vapor Pressure e mm Hg (2)	Wind Speed at 2m V m/s	Short Wave Radiation Flux Ra g-cal/cm²/day (3)	% of Possible Sunshine n/D	Radiation Absorbed Ri g-cal/cm²/day	Outward flow of Longwave Radiation Rb g-cal/cm²/day	Net Radiation Rn=Ri-Rb g-cal/cm²/day	Hv g-cal/cm³ (4)	Evaporation Rates E mm/day (5)	Water Surface Temp Tw °C (6)	Delta	Evaporation in Air Eao mm/day	Evaporation at Water Surface Hw mm/day	Evaporation at Water Surface Hw in/month
Jan.	28.9	-1.72	271.28	0.725	4.046	2.93	4.78	370.29	0.38	127	109	18	596.9	0.31	-2.20	2.33	1.10	0.45	0.527
Feb.	32.1	0.06	273.06	0.7025	4.562	3.20	4.65	549.57	0.42	198	116	82	596.0	1.37	0.00	24.43	1.31	1.37	1.620
Mar.	41.8	5.44	278.44	0.6725	6.74	4.53	4.96	670.11	0.49	262	128	134	593.2	2.26	0.00	0.41	2.26	2.26	2.673
Apr.	53.5	11.94	284.94	0.64	10.478	6.71	4.78	850.02	0.56	359	136	223	589.8	3.78	2.00	0.38	3.74	3.76	4.437
May.	63	17.22	290.22	0.675	14.726	9.94	3.89	929.19	0.6	409	129	280	587.0	4.77	5.00	0.39	3.92	4.30	5.076
June	71.4	21.89	294.89	0.6925	19.688	13.63	3.53	998.57	0.65	461	119	342	584.6	5.86	8.00	0.44	4.54	5.16	6.098
July	75.4	24.11	297.11	0.715	22.513	16.10	3.17	939.69	0.67	442	109	334	583.5	5.72	9.00	0.42	4.37	5.00	5.905
Aug.	74.1	23.39	296.39	0.73	21.567	15.74	3.04	844.98	0.65	390	108	283	583.8	4.84	8.00	0.38	3.82	4.27	5.039
Sept	67.5	19.72	292.72	0.7325	17.232	12.62	3.31	725.17	0.66	338	124	215	585.7	3.66	5.00	0.31	3.26	3.42	4.036
Oct.	55.3	12.94	285.94	0.7025	11.182	7.86	3.62	537.54	0.5	213	120	93	589.3	1.58	1.00	0.28	2.55	2.20	2.593
Nov.	43.4	6.33	279.33	0.7175	7.172	5.15	4.29	409.11	0.36	137	103	34	592.7	0.57	0.00	0.32	1.82	1.32	1.558
Dec.	33.8	1.00	274.00	0.7425	4.92	3.65	4.56	330.65	0.32	105	98	7	595.5	0.12	0.00	1.27	1.20	0.42	0.494

Annual total (in) 40.05

Notes:
Weather data are mean monthly data for Cincinnati, Ohio, National Oceanic and Atmospheric Administration (NOAA), Part I Eastern Region, 1987.
The amount of evaporation from open water surface was computed with Penman equation presented in McCUEN, 1989.
(1) From Table 14-1, Mc CUEN, 1989.
(2) $e = e_s * R_h$
(3) From Table 14-3, Mc CUEN, 1989.
(4) Hv = 596 - 0.52*Tc
(5) E = 1-*Rn/Hv
(6) Water surface temperature was estimated based on the ambient temperature.

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3.0 CONCEPTUAL MODEL FORMULATIONS

The analytical implementations of the conceptual model presented in Section 2.0 are described in this section. The general technical rational and basic equations that account for the routing processes is presented first. Then, the inflow and outflow components such as rainfall, runoff, evaporation, and infiltration are described based on site-specific information. Finally, the pond overflow equation and sizing of the discharging channels are described.

3.1 STORAGE ROUTING MODEL EQUATION

As described in the conceptual model, storage routing is the process of estimating the passage of a storm or flood hydrograph through a retention facility. For the purpose of developing routing model through the retention pond, the mass balance which states the difference between inflow and outflow equals to the pond storage change can be expressed as (see Figure 2-1)

$$I(t) - O(t) = \frac{dS_P(t)}{dt} \qquad (1)$$

where

- I(t) is the inflow into the pond per unit time,
- O(t) is the outflow from the pond per unit time,
- $S_p(t)$ is the pond storage at time t, and
- t is the time.

If the month is used as the unit time, and finite difference is applied to Eq. (1), The mass balance equation can be written as:

$$I(i) - O(i) = S_P(i+1) - S_P(i) \qquad (2)$$

Or

$$S_P(i+1) = S_P(i) + I(i) - O(i) \qquad (3)$$

where

$I(i)$ is the total inflow into the pond in the month i,

$O(i)$ is the total outflow from the pond in the month i,

$S_p(i+1)$ is the pond storage at the end of month i+1, and

$S_p(i)$ is the pond storage at the end of month i.

The pond storage at the end of month i+1 can be calculated from Eq. (3) by assigning the pond storage at the end of month i (initial pond storage) and inflow and outflow in month i.

3.2 INLOW COMPONENTS : RAINFALL AND RUNOFF

As shown in Figure 2-1, the inflow term I(i) consists of two terms: runoff from the drainage area and rainfall directly into the pond. It can be expressed as:

$$I(i) = ROF(i) \times A_d + RAIN(i) \times A_p \qquad (4)$$

where

ROF (i) is the runoff per unit area in month i,

RAIN (i) is the rainfall per unit area in month i,

A_d is drainage area, and

A_p is the pond surface water area at stage of H.

The monthly average rainfall depth and runoff were used in the calculations.

It is also assumed that the change of pond surface water area will not change the drainage area. Surface water area of pond (A_p) is the function of the stage for a specific pond:

$$A_p = f_{Ap}(H(i)) \qquad (5)$$

Where H(i) is the pond surface water elevation in month i.

Substituting equation (5) into equation (4) will yield the following equation

$$I(i) = ROF(i) \times A_d + RAIN(i) \times f_{Ap}(H) \qquad (6)$$

The monthly average rainfall was obtained from the database of the National Oceanic and Atmospheric Administration (NOAA). The recorded length obtained for the monthly mean rainfall from NOAA is approximately 30 years.

The monthly runoff was calculated by using HELP model based on the monthly rainfall data from NOAA. Appendix A presents the monthly runoff depth calculations (HELP model). The drainage area (Ad) is determined from the topographic map.

3.3 OUTFLOW COMPONENTS :EVAPORATION, INFILTRATION AND OVERFLOW

The outflow components considered in the model were evaporation from the open water surface and infiltration (see Figure 2-1). Equation (7) describes their relationship.

$$O(i) = Hw(i) \times A_P + Inf(i) \times A_P + \text{Pond Overflow} \tag{7}$$

where

O(i) is the total loss of the water in the month (i)

Hw(i) is the evaporation rate (per unit area) in month i, and

Inf(i) is the infiltration rate (per unit area) to subsurface in month i.

Evaporation rate E will be directly incorporated into Equation (7), if pan evaporation data are available. The evaporation rate was estimated using the Penman equation based on meteorological data from the climate station of Cincinnati, Ohio, since pan evaporation data is not available. The following two subsections present the evaporation and infiltration model.

3.3.1 Evaporation Simulation

The Penman equation was used for estimating evaporation from open water surface. Penman proposed the following simplified energy balance equation (McCUEN, 1989):

$$H_W = \frac{\Delta E + \alpha \ E_{a0}}{\Delta + \alpha} \tag{8}$$

Where

Hw = evaporation from water surface (mm/day),

E_{a0} =0.35 (e_s-e) (0.2+0.55V),

e=e_sxR_h,

R_h is the relative humidity,,

e is the vapor pressure at air temperature,

e_s is the saturated vapor pressure, and is a function of temperature,

V is the wind velocity at 2 meter high, and

α is the psychometric constant, the typical value is 0.485 mm Hg/°C

$$\Delta = \frac{e_0 - e_a^{\bullet}}{T_0 - T_a} \tag{9}$$

Δ is the slope of the saturated vapor pressure curve at mean temperature,

T_0 and T_a are temperature of the water surface and air, respectively,

e_0 is the vapor pressure of the water surface, and $e_a^{\bullet}$ is the saturation vapor pressure at T_a.

$$E = 10\frac{R_n}{H_v} \tag{10a}$$

$$R_n = R_I - R_B \tag{10b}$$

R_n is the net radiation in units of g-cal/cm²-day,

R_I is the amount of radiation absorbed, and is a function of short-wave radiation function,

R_B is the outward flow of long-wave radiation.

R_I and R_B can be expressed as below:

$$R_I = R_A(1-r)(a+b\frac{n}{D}) \tag{10c}$$

$$R_B = \sigma T_a^4(0.47-0.077\sqrt{e})(0.2+0.8\frac{n}{D}) \tag{10d}$$

$$H_V = 596 - 0.52T \tag{10e}$$

Where

r is the reflection coefficient,

a and b are empirical coefficients that are location dependent,

n/D is the fraction of possible sunshine,

R_A is the Angot's values of short-wave radiation flux in units of g-cal/cm^2/day, and is a function of the latitude and the month of the year,

σ =117.7 x 10^9 g-cal/cm^2/day

H_V is in unit of g-cal/cm^3,

T is the temperature, in °C.

3.3.2 Infiltration Simulation

The amount of infiltration through the pond liner material has incorporated the data presented in the infiltration zone model in the Feasibility Study Report (FS Report) (DOE, 1995). Based on the Figures F-1 and F-2 in Appendix F of FS, bottom liner material is mainly the gray clay located at the base of the glacial overburden layer. Part of Pond 1 liner materials is the unsaturated Great Miami Aquifer material. The gray clay is a clay-rich glacial till deposit, with an average porosity of 0.20. The reported hydraulic conductivity for gray clay is 7.23 x 10^{-7} cm/sec. The thickness of the liner was assumed to be 3 feet.

The infiltration rates will follow Darcy's Law, and can be described as below:

$$Inf(i) = K\frac{H(i) - H_{GW}(i)}{TH} \tag{11}$$

where

K is the hydraulic conductivity of the pond liner,

H (I) is the water surface elevation of the pond in month I,

H_{GW} (I) is the higher value between liner bottom elevation and groundwater elevation, and

TH is the pond liner thickness.

Eq.(11) indicates that if Inf(i) is positive, flow is from surface water in the pond to groundwater, if Inf(i) is negative, flow is from groundwater to surface water.

3.3.3 Pond Overflow

It is assumed that overflow will take place in a pond when the surface water elevation in the pond is higher than a certain elevation (pond overflow elevation). For normal conditions, the daily overflow rates were estimated by dividing the total amount of overflow in a month by 30 days. For extreme conditions, if the pond surface water is higher than the pond overflow elevation, then water will overflow until the pond stage is just at or below the pond overflow elevation. The overflow equation is stated as follow:

$$Q = 3.3LH^{1.5} \tag{12}$$

where

Q is the flow rates in ft^3/sec.

L is the weir width in feet.

H is the water depth above the weir bottom in feet.

3.4 STORAGE ROUTING COMPUTATION PROCEDURES

Substituting the Equations of (6), (7), (8) and (11) into Equation (3) will yield following routing equation:

$$\begin{aligned} S_P(i+1) &= S_P(i) + ROF(i) \times A_d + RAIN \times f_{Ap}(H(i)) \\ &\quad - Hw(i) \times f_{Ap}(H(i)) - K\frac{H(i) - H_{GW(i)}}{TH} f_{Ap}(H(i)) - Overflow \end{aligned} \tag{13}$$

Equation (13) can be used to calculate the pond storage $S_p(i+1)$ starting from month i. For example, the computation starts from month 0 (i=0) to calculate the pond storage term $S_p(1)$ at month 1. The $S_p(0)$ is given as the initial condition. The runoff (ROF), rainfall (RAIN), H(i), and Hw(i) in month 0 will be calculated explicitly. The pond storage Sp(1) at month 1 can then be calculated , since the terms on the right side of Equation (13) are all known.

3.5 SIZING OF CONNECTION CHANNELS

The hydraulic connections are necessary for regulation of the pond storage, maintaining minimum depth and open water space for surface water habitats. The current hydraulic connection plan utilizes outlet facilities such as weirs and open channels for the conveyance of water between ponds or discharging to SSOD. As stated in Section 2.0, the connection plan requires two discharging channels. The first channel drains excessive water from Pond 1 to SSOD. The second channel discharges the excessive water from Pond 2 to Pond 4 (the retention pond).

Sizing the discharging channel is based on outflow rates through the outlet weirs. The outflow rates were determined from the routing model under the extreme conditions. A grass lined trapezoidal channel with side slope of 1V:1H is proposed. Manning's equation is used for estimating the depth of water in the channel, assuming a width for the channel. This computation was performed using FLOWMASTER, a sizing program for channels and pipes (Haestad, 1990).

4.0 POND MODELING RESULTS UNDER NORMAL CONDITIONS

This section presents the storage routing modeling results under normal conditions. The normal conditions are represented by considering the monthly average meteorological data. As stated in Section 2.0, monthly mean data of rainfall depth, temperature, the fraction of possible sunshine, relative humidity, and wind speed were used for developing the monthly routing model. The conceptual routing model as presented in section 2.0 is the basis for calculating the storage and passage of runoff generated by a normal rainfall event. The routing equation described in Section 3.0 defines the water budget of a watershed. The water balance is a physical analysis of the drainage basin based on the conservation of mass, which assumes that the rates of change of storage is equal to the difference between the inflow and outflow. Inflow parameters considered in the normal climate conditions are monthly rainfall and runoff. The monthly mean rainfall data source is based on data available from NOAA. Runoff depths were calculated using the HELP model. Outflow parameters considered are evaporation from the pond surface and infiltration through the liner material. The simulation time selected was four years and represents the normal conditions in order to reach an equilibrium state. Tables C-1 through C-4 in Appendix C present the detailed monthly calculations for a period of four years. The following sections present the results of the routing model by considering the monthly average meteorological record.

4-1 INPUT PARAMETERS

The input data to the routing model used for the normal conditions are briefly summarized in this subsection.

Drainage Area. The drainage areas are the total of each individual subbasin, and each subbasin is plannimetered based on the enlarged scale of the post-excavation topographic map. The drainage area for the four ponds are estimated as 127.4,109.1,104, and 49.3 acres respectively. Table 2-1 presents the subbasin areas and their total drainage areas.

Pond Bottom Elevations. Bottom elevations of the four ponds are designed at 555, 550, 565, and 535 feet respectively (Appendix C).

Monthly Mean Rainfall. The monthly mean precipitation was based on the database from NOAA (NOAA, 1986). They are presented within EXCEL calculation tables in Appendix C.

Monthly Mean Runoff. The monthly mean runoff was calculated by using the HELP model based on the monthly mean precipitation data from NOAA. The monthly mean runoff depths were presented in Appendix C.

Evaporation Model Input Parameters. In Penman's model, the following monthly mean input parameters are considered: air and water surface temperature, relative humidity, saturated vapor pressure, wind velocity, short-wave radiation flux, and percent of possible sunshine. (NOAA, 1987). Other input parameters that are not time dependent are the latitude, reflection coefficient, and psychrometric constant. The input data are presented in Table 2-4.

Pond Liner Hydraulic Conductivity. A Hydraulic Conductivity of 7.23×10^{-7} cm/sec for natural gray clay as shown in Figure 2-5 was used for modeling. As discussed in Section 2.0, the liner materials for Pond 1 requires replacement with materials that have similar hydraulic conductivity in the range of 10^{-6} to 10^{-7} cm/sec.

Thickness of Pond Liner. The thickness of pond liner is proposed as three feet for the four ponds.

Pond Overflow Elevations. Overflow elevations of the four ponds are designed as 573, 573, 578, and 560 feet respectively.

Groundwater Elevation. The typical groundwater elevation in the pond areas is reported as 520 feet.

4.2 POND INFLOW AND OUTFLOW HYDROGRAPH

Figures 4-9, 4-13, 4-17, and 4-21 present inflow and outflow hydrographs for the four ponds respectively. As shown in these figures, the total inflow volume on a monthly basis are generally higher in the first part of the year, and are lower for the months between May and November for the four ponds. Table 4-1 presents the maximum inflow rates and maximum outflow rates for the four ponds. As indicated in Table 4-1 and Figures 4-9, 4-13, 4-17, and 4-21, Pond 1 will receive the highest runoff in April among the four ponds, and also has nearly the highest outflow rates.

TABLE 4-1

MAXIMUM INFLOW RATES AND MAXIMUM OUTFLOW RATES
UNDER NORMAL CONDITIONS

	Maximum Inflow Rates (ft^3 /month)	Maximum Outflow Rates (ft^3 /month)
POND 1 (Northeast of FEMP)	$1.1x10^6$	$8.71x10^5$
POND 2 (Northwest of FEMP)	$9.81x10^5$	$6.19x10^6$
POND 3 (Southeast of FEMP)	$9.06x10^5$	$8.13x10^5$
POND 4 (Retention Pond)	$4.20x10^5$	$2.36x10^5$

4.3 POND MONTHLY STORAGE VARIATIONS

Figures 4-10, 4-14, 4-18, and 4-22 present monthly pond storage variations for the four ponds respectively. As shown in these figures, the storage volume on a monthly basis are generally higher in the first part of the year, and decrease from April or May to the end of the year for the four ponds. Also, the storage variations experienced within each pond are about the same in order of magnitude. Table 4-2 presents the maximum and minimum pond storages for each pond under normal conditions. Table 4-3 presents the monthly pond storage variations under normal conditions.

TABLE 4-2

MAXIMUM AND MINIMUM POND STORAGE UNDER NORMAL CONDITIONS

	Maximum Storage (ft^3)	Minimum Storage (ft^3)
POND 1 (Northeast of FEMP)	$4.45X10^6$	$3.05X10^6$
POND 2 (Northwest of FEMP)	$6.19X10^6$	$4.74X10^6$
POND 3 (Southeast of FEMP)	$1.93X10^6$	$1.25X10^6$
POND 4 (Retention Pond)	$2.55X10^6$	$2.12X10^6$

4.4 POND MONTHLY STAGE VARIATIONS

Figures 4-11, 4-15, 4-19, and 4-23 present monthly pond stage variations for the four ponds respectively. Figures 4-1 through 4-8 present the pond water surface outlines with maximum and minimum storage for the four ponds. As indicated in the figures, stage variations in Pond 1 is relatively high when compared to the other ponds. This is due to the relatively smaller pond storage capacity, however, Pond 1 has a higher volume of runoff generated by a larger drainage area. Table 4-4 presents the stage changes for each pond. As indicated in the table, Pond 2 has the largest freeboard (about 7 to 8 feet) below the top edge of the pond. For this reason, Pond 2 collects less runoff, and will be excavated in a relatively large area during the soil remediation. Pond 3 serves as a temporary stormwater detention basin. Stormwater in Pond 3 can be overflowed to the SSOD. Of the four ponds, Pond 4 is the smallest one. Pond 4 also has a much lower rate of inflow, and can be functioned as an intermediate retention basin. As indicated in Table 4-4, difference in pond freeboard between Pond 1 and Pond 2 is approximately 6 feet. It would be more efficient for the purpose of storage routing, if a hydraulic connection is installed between Pond 1 and Pond 2.

Table 4-5 presents the monthly stage variations for each pond. As can be seen in Table 4-5, stage variations in Pond 3 (ranged from 576.3 to 578 feet) is the greatest among the four ponds in the same month. Pond 1 (ranged from 570.3 to 573 feet) has the second highest pool level. As mentioned in

Table 4-3 Monthly Storage Variations Under Normal Conditions

Month	Pond Water Storage (ft^3)			
	Pond 1	Pond 2	Pond 3	Pond 4
Jan	3.08E+06	4.75E+06	1.31E+06	2.13E+06
Feb	3.63E+06	5.23E+06	1.80E+06	2.34E+06
Mar	4.45E+06	5.96E+06	1.93E+06	2.55E+06
Apr	4.45E+06	6.19E+06	1.60E+06	2.54E+06
May	4.01E+06	5.96E+06	1.51E+06	2.46E+06
Jun	3.83E+06	5.75E+06	1.45E+06	2.40E+06
Jul	3.64E+06	5.52E+06	1.39E+06	2.34E+06
Aug	3.63E+06	5.44E+06	1.46E+06	2.33E+06
Sep	3.43E+06	5.20E+06	1.37E+06	2.26E+06
Oct	3.26E+06	4.99E+06	1.31E+06	2.20E+06
Nov	3.11E+06	4.81E+06	1.25E+06	2.14E+06
Dec	3.05E+06	4.74E+06	1.25E+06	2.12E+06

Section 2.0, Pond 3 serves as temporary runoff control, therefore, the higher stage is maintained for a short period of time. The stages simulated for Pond 1 would remain for a certain amount of time until the pool level exceeds the outlet elevation of 573 feet, then overflows to SSOD.

TABLE 4-4

MAXIMUM AND MINIMUM POND STAGE UNDER NORMAL CONDITIONS

	Pond Stage		**Pond Top**
	Maximum (feet)	Minimum (feet)	**Edge Elevation** (feet)
POND 1 (Northeast of FEMP)	573.0	570.32	575
POND 2 (Northwest of FEMP)	566.71	564.19	575
POND 3 (Southeast of FEMP)	578.0	576.29	580
POND 4 (Retention Pond)	560.0	556.9	575

Note: The maximum stage occurs in April, while the minimum stage occurs in December.

4.5 POND DAILY OVERFLOW RATE

Figures 4-12, 4-16, 4-20, and 4-24 present daily overflow rates for the four ponds respectively. As shown in these figures, the daily overflow rate occurs normally in April in response to the higher inflow rates. In general, the daily overflow rates are determined by the bottom elevation of pond outlets facilities. Table 4-6 presents the maximum daily overflow rates and bottom elevations of pond outlets for each pond under normal conditions. As indicated in table 4-6, the daily overflow rate is zero for Pond 2, since the pool level in Pond 2 has never reached the designed overflow elevation of 573 feet.

ele

Table 4-5 Monthly Stage Variations Under Normal Conditions

Month	Pond Surface Water Elevation (ft)			
	Pond 1	Pond 2	Pond 3	Pond 4
Jan	570.4	564.2	576.5	557.0
Feb	571.4	565.1	577.7	558.5
Mar	573.0	566.3	578.0	560.0
Apr	573.0	566.7	577.2	559.9
May	572.2	566.3	577.0	559.4
Jun	571.8	566.0	576.8	558.9
Jul	571.5	565.6	576.6	558.5
Aug	571.4	565.5	576.8	558.5
Sep	571.1	565.1	576.6	558.0
Oct	570.7	564.7	576.5	557.5
Nov	570.4	564.3	576.3	557.1
Dec	570.3	564.2	576.3	556.9

TABLE 4-6

MAXIMUM DAILY OVERFLOW RATE UNDER NORMAL CONDITIONS

	Daily Overflow Rate (ft^3/day)	Pond Outlet Elevations (feet)
POND 1 (Northeast of FEMP)	$7.46X10^3$	573
POND 2 (Northwest of FEMP)	0	573
POND 3 (Southeast of FEMP)	$2.09X10^4$	578
POND 4 (Retention Pond)	$4.22X10^3$	560

4.6 MAXIMUM AND AVERAGE DEPTH OF THE PONDS

The maximum depth was computed as the difference between the water surface elevation and the pond bottom elevation. The average depth was determined by dividing the storage by the surface water area. Table 4-8 presents the maximum and average water depths under normal conditions. As indicated in Table 4-8, the highest maximum and average depths generally occur in April. The highest maximum water depths estimated for the four ponds are 18, 16.7, 13, and 25 feet respectively. The highest average water depths estimated for the four ponds are 8.2, 10.5, 4.5, and 14.8 feet respectively.

MAX

Table 4-7 Maximum and Average Depth Under Normal Conditions

Month	Pond 1		Pond 2		Pond 3		Pond 4	
	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)
Jan	15.38	7.00	14.22	8.75	11.31	4.49	20.87	13.64
Feb	16.43	7.55	15.13	9.31	12.49	4.31	22.30	14.08
Mar	18.00	8.22	16.33	10.20	13.00	4.26	24.65	14.71
Apr	18.00	8.22	16.71	10.46	12.33	4.33	25.00	14.79
May	17.16	7.88	16.34	10.20	12.07	4.36	24.00	14.55
Jun	16.82	7.73	15.99	9.95	11.87	4.39	23.44	14.40
Jul	16.46	7.57	15.60	9.67	11.67	4.42	22.89	14.25
Aug	16.43	7.55	15.47	9.57	11.81	4.40	22.79	14.22
Sep	16.06	7.37	15.08	9.27	11.57	4.44	22.21	14.06
Oct	15.73	7.19	14.69	9.03	11.38	4.47	21.68	13.90
Nov	15.43	7.03	14.33	8.82	11.20	4.51	21.18	13.74
Dec	15.32	6.96	14.19	8.73	11.18	4.52	20.92	13.65

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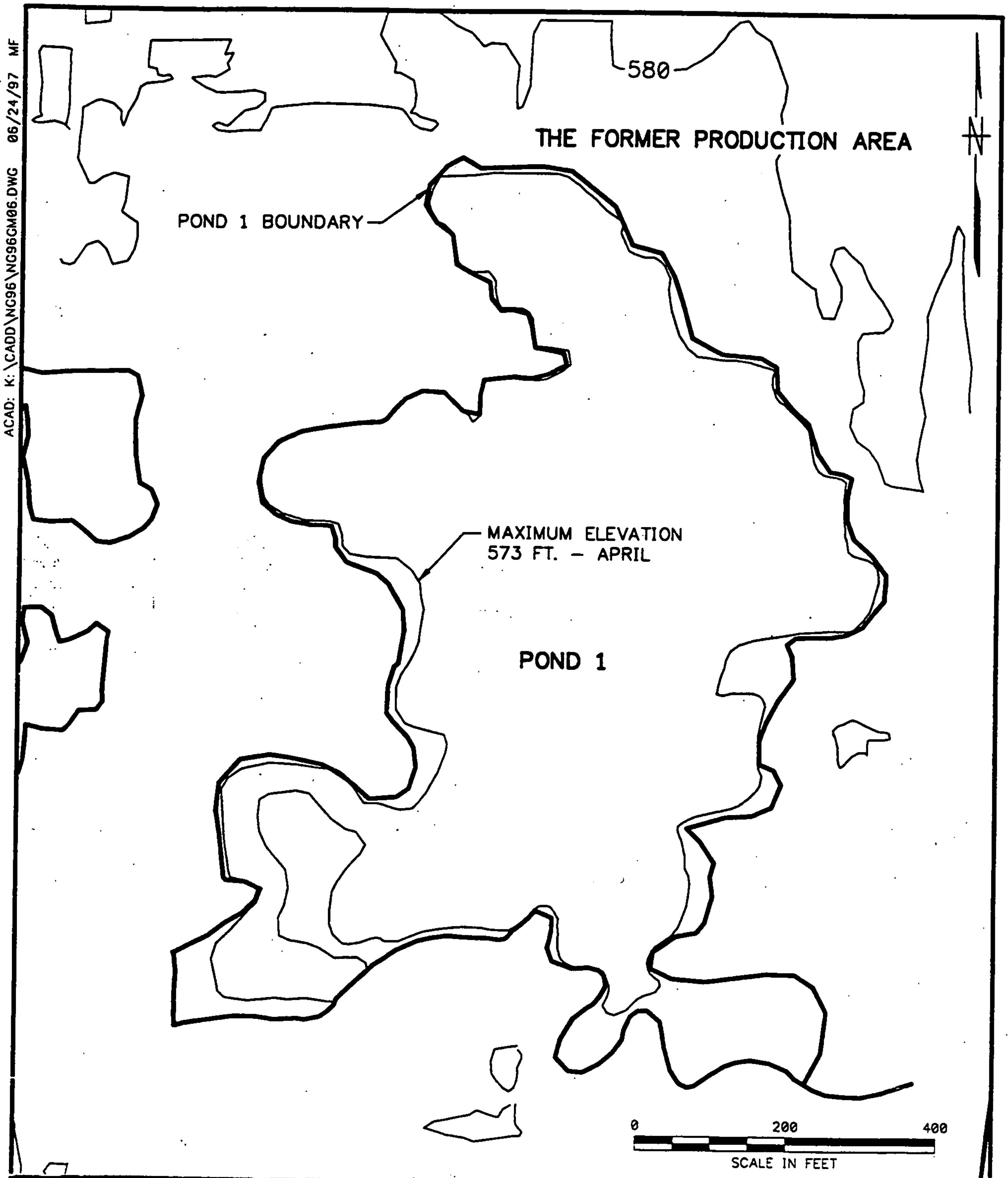

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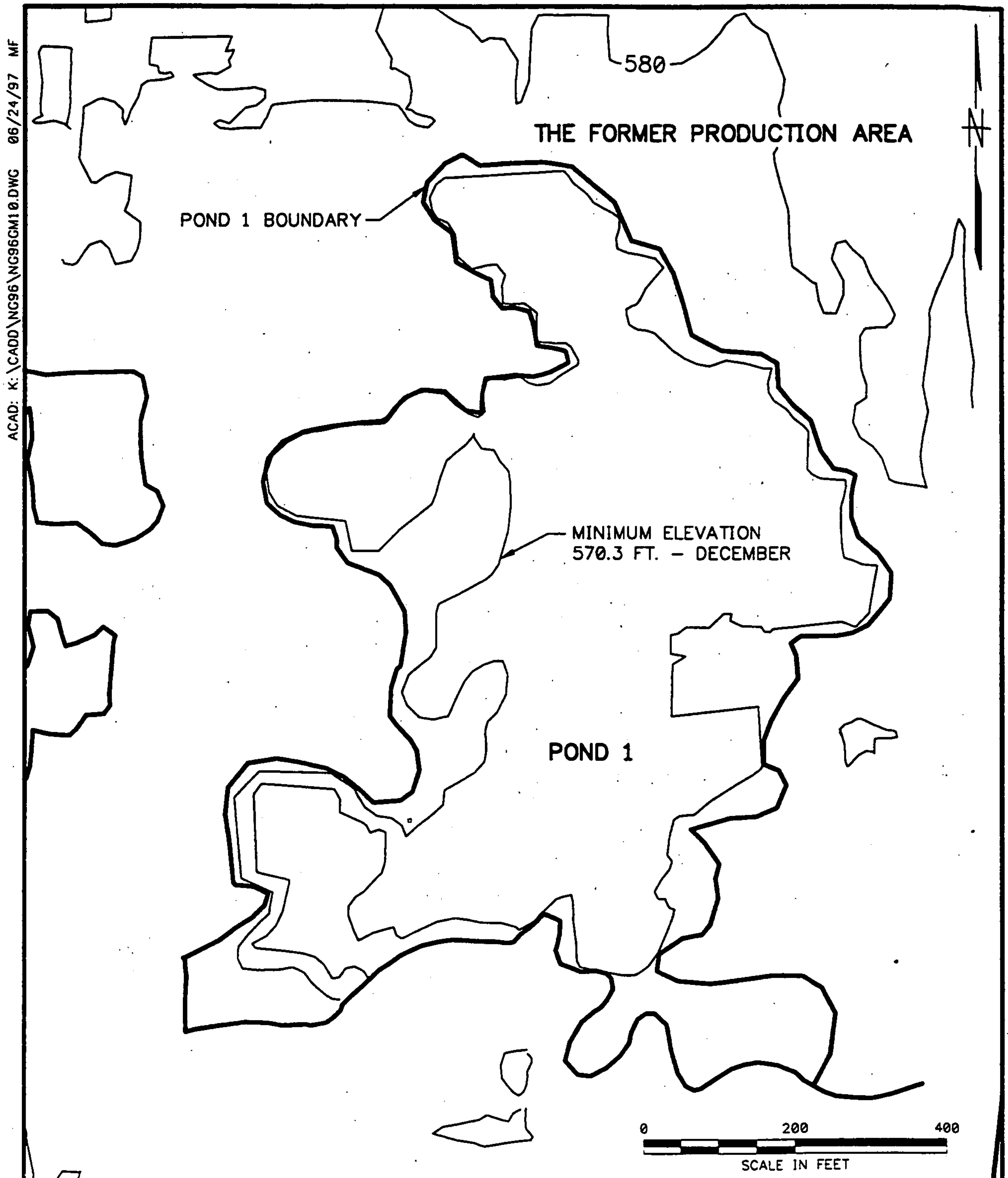
CHECKED BY DATE	POND 1 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-1	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97



DRAWN BY DATE DLT 6/13/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 1 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MINIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED–AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 4–2	REV. 0

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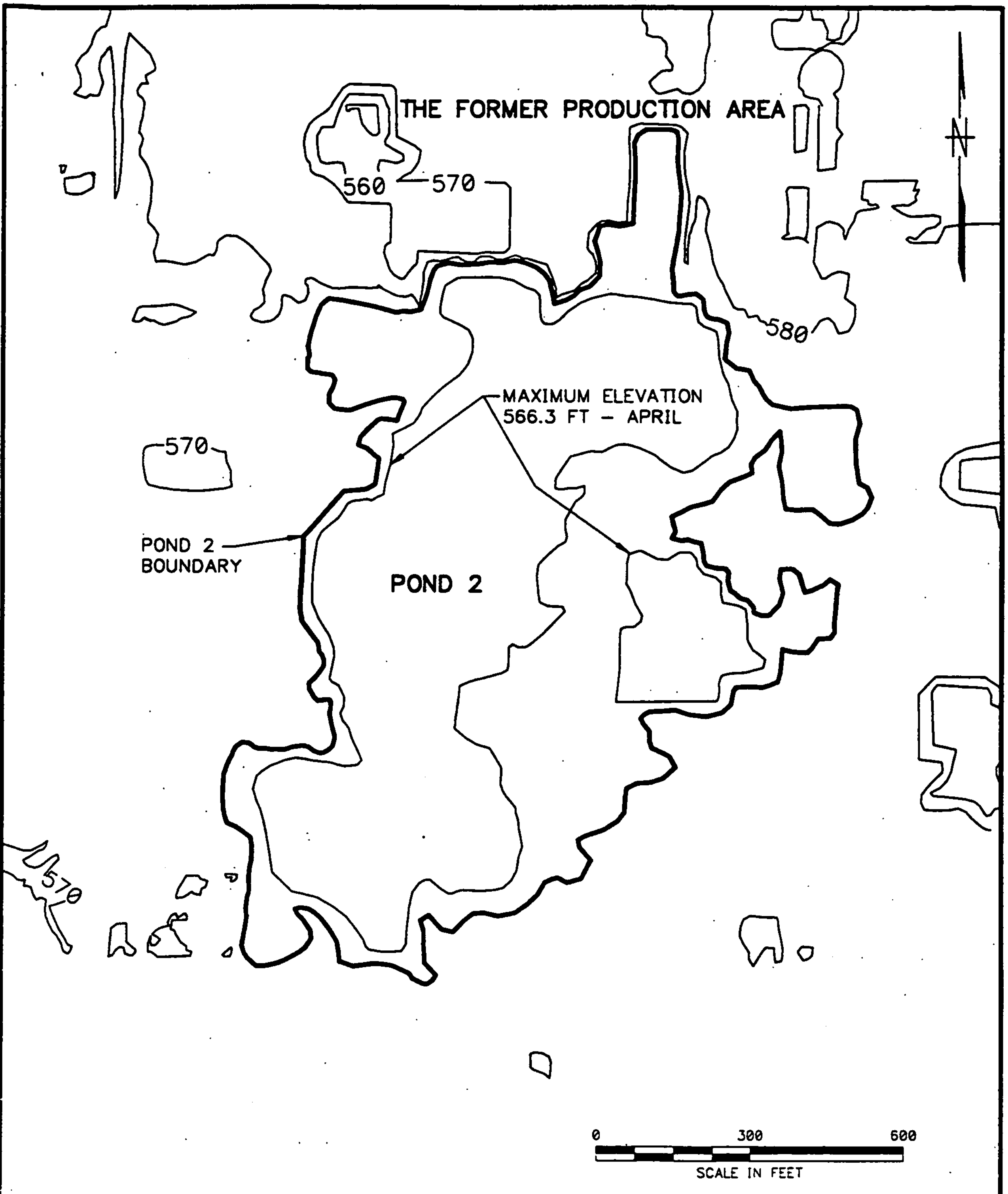

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CHECKED BY	DATE	POND 2 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA			APPROVED BY	DATE
SCALE AS NOTED			DRAWING NO. FIGURE 4-3	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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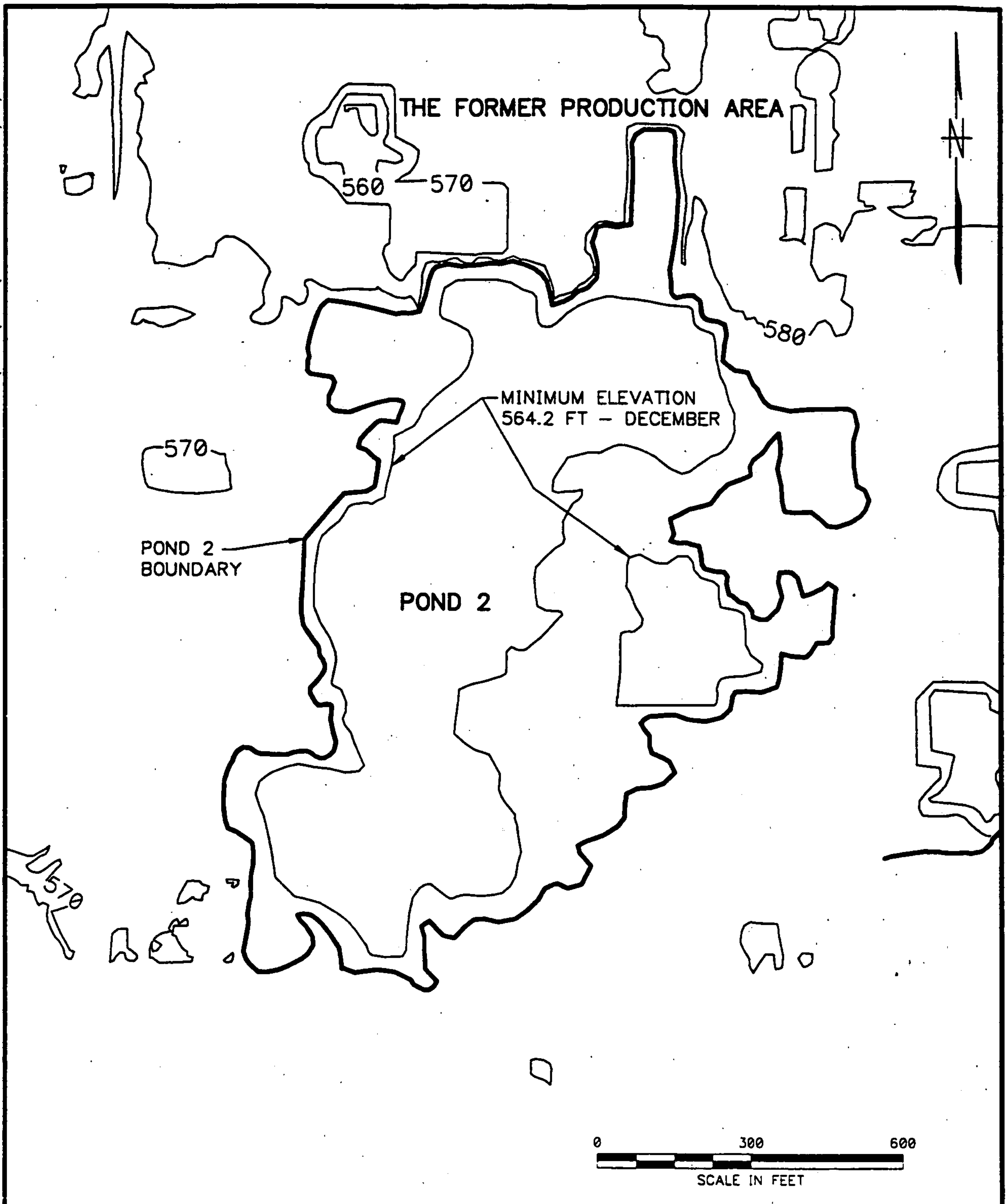

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COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 4–4	REV. 0

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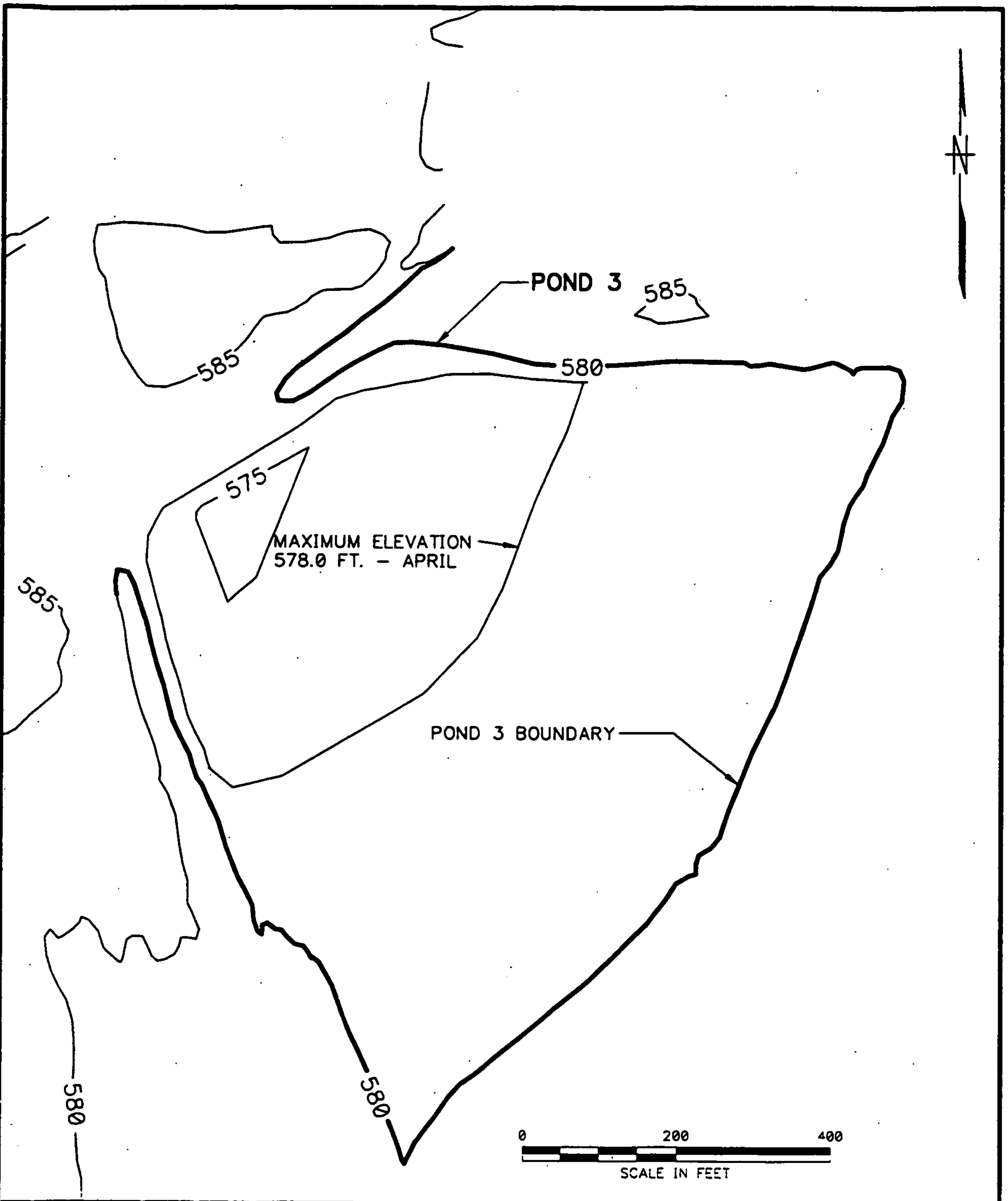

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COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 4-5	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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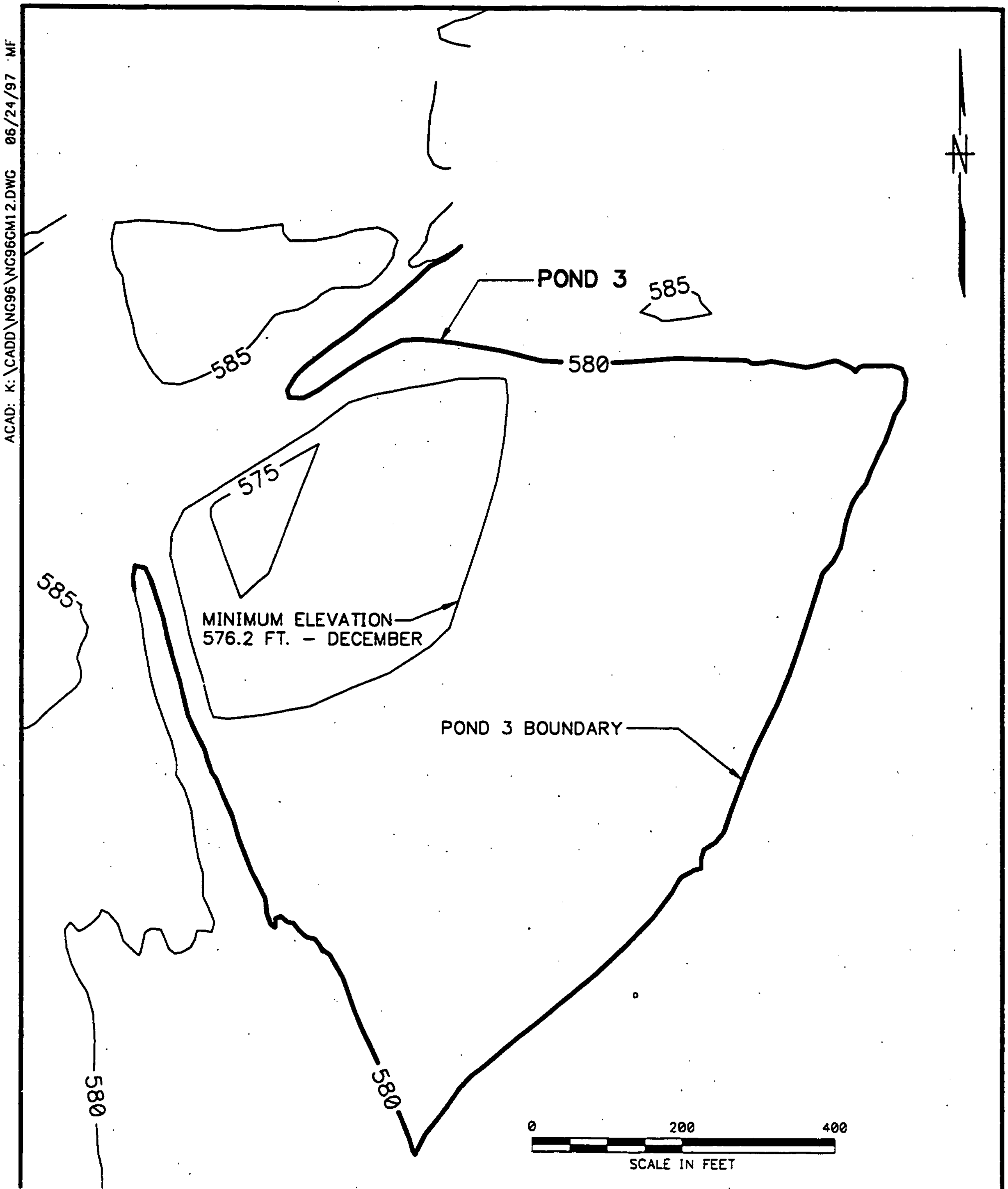

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CHECKED BY	DATE	POND 3 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MINIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA			APPROVED BY	DATE
SCALE AS NOTED			DRAWING NO. FIGURE 4-6	REV. 0

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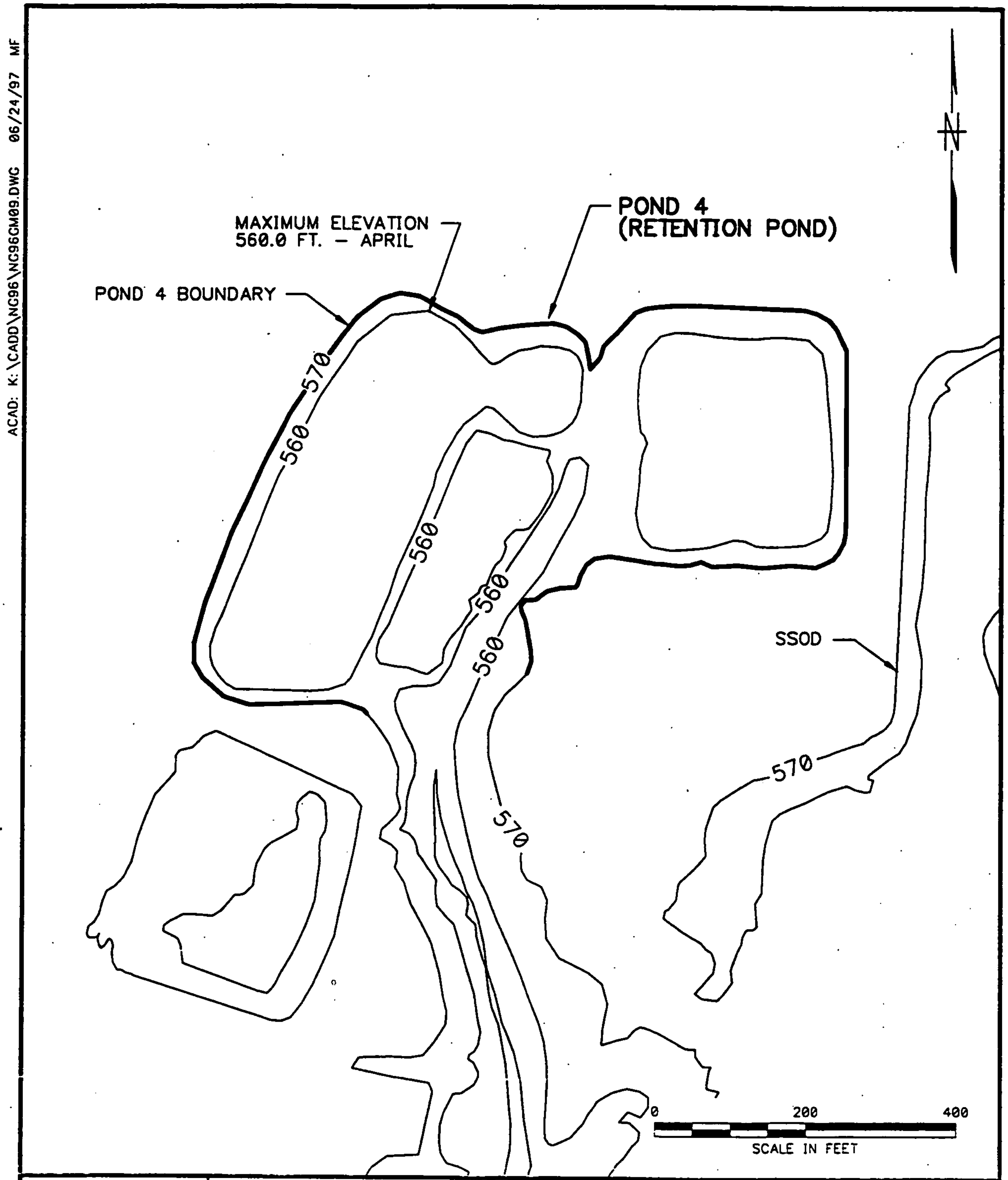

DRAWN BY GMF	DATE 6/16/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY	DATE	POND 4 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA			APPROVED BY	DATE
SCALE AS NOTED			DRAWING NO. FIGURE 4-7	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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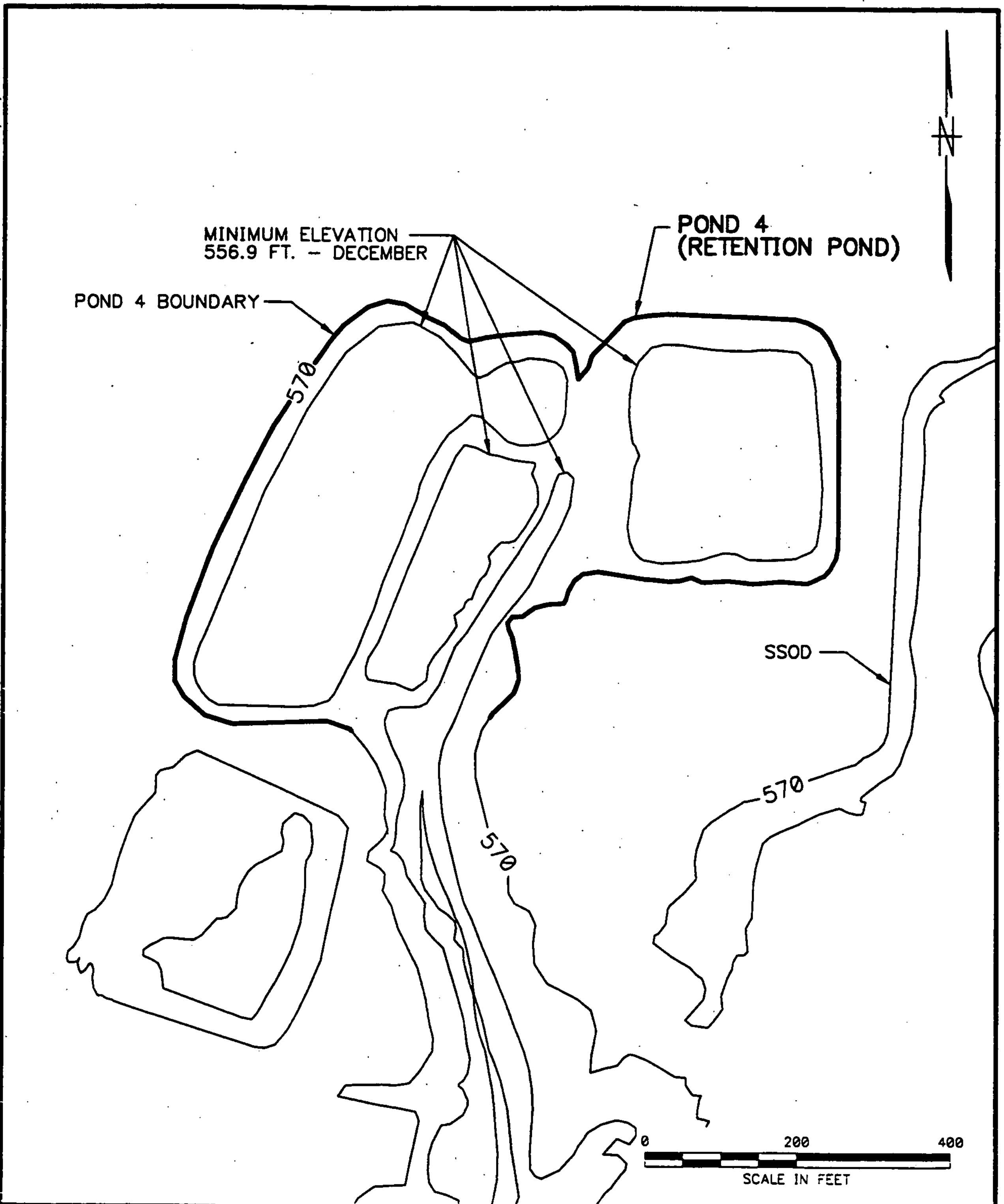

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CHECKED BY	DATE	POND 4 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MIMIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA			APPROVED BY	DATE
SCALE AS NOTED			DRAWING NO. FIGURE 4-8	REV. 0

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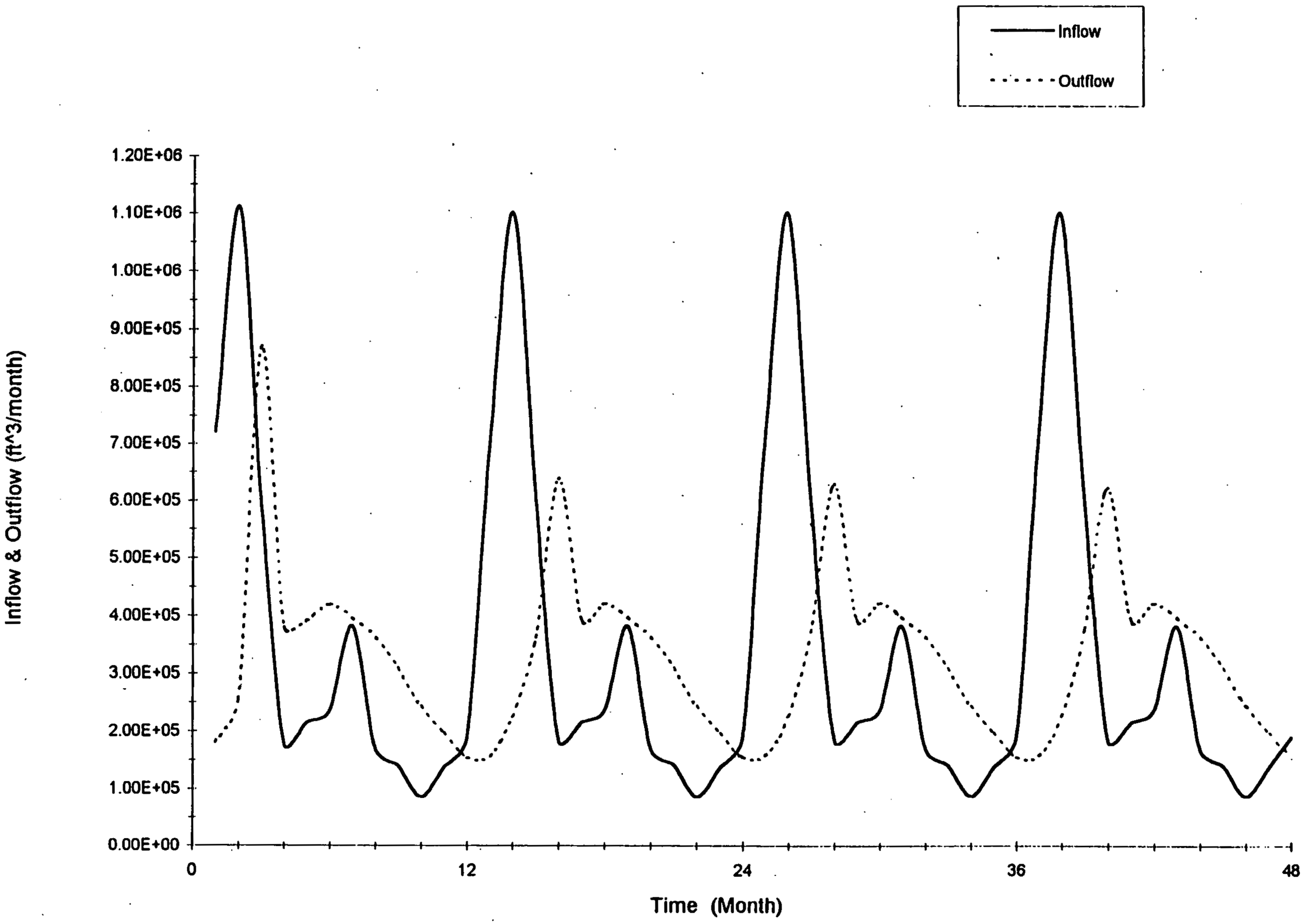

Figure 4-9 Monthly Inflow And Outflow Rates of Pond 1

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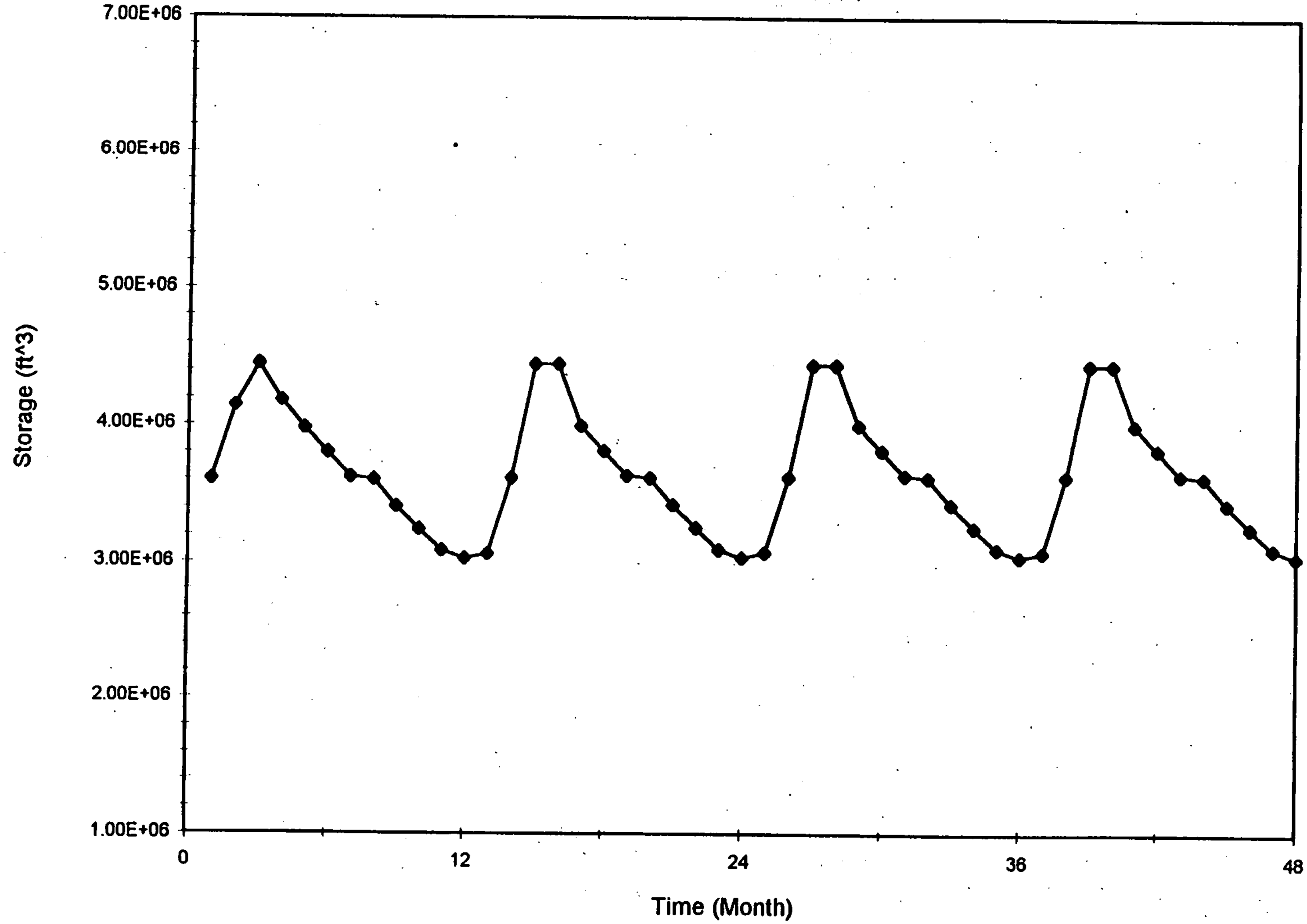

Figure 4-10 Monthly Storage Variations of Pond 1

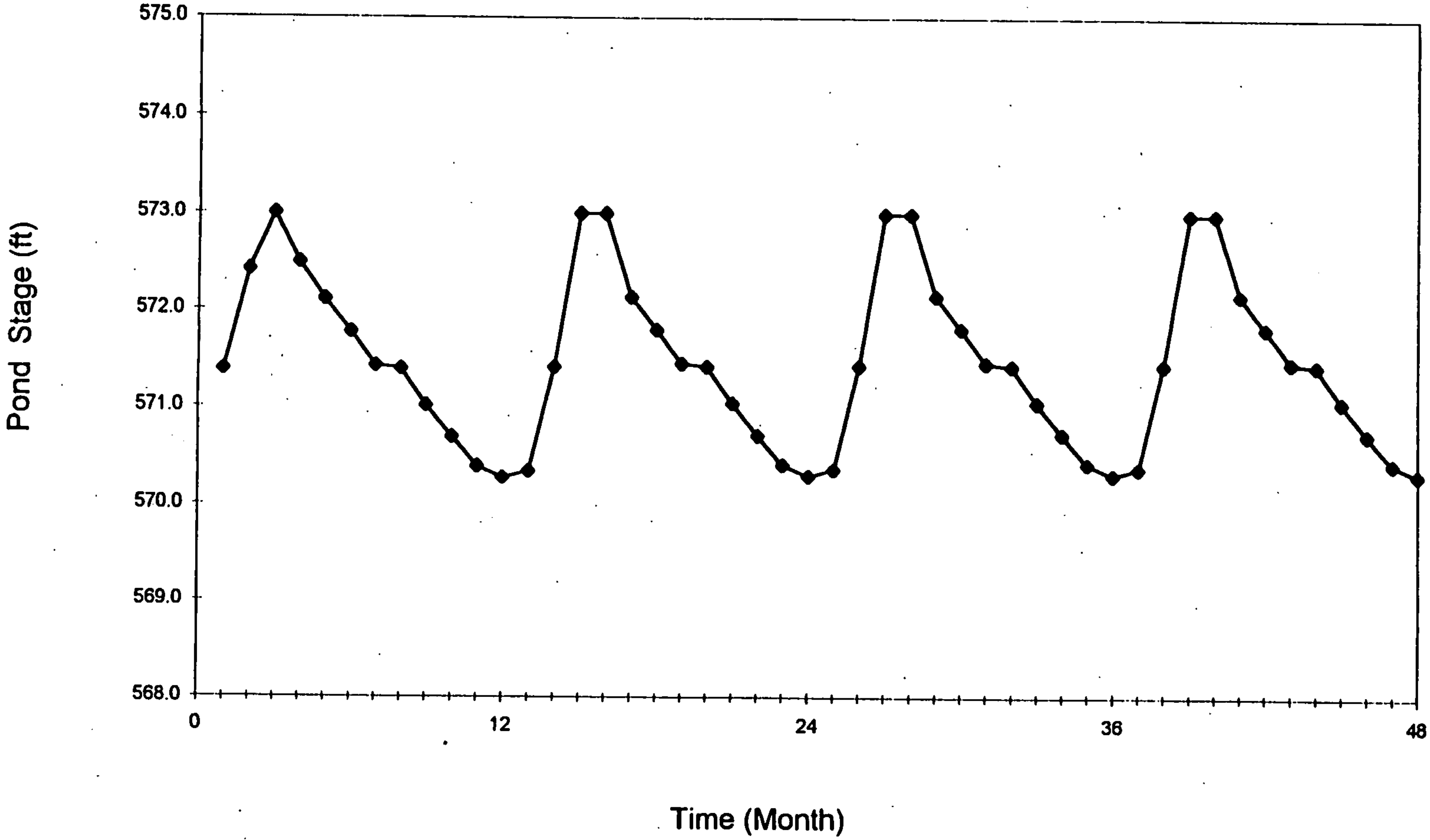

Figure 4-11 Monthly Stage Variations of Pond 1

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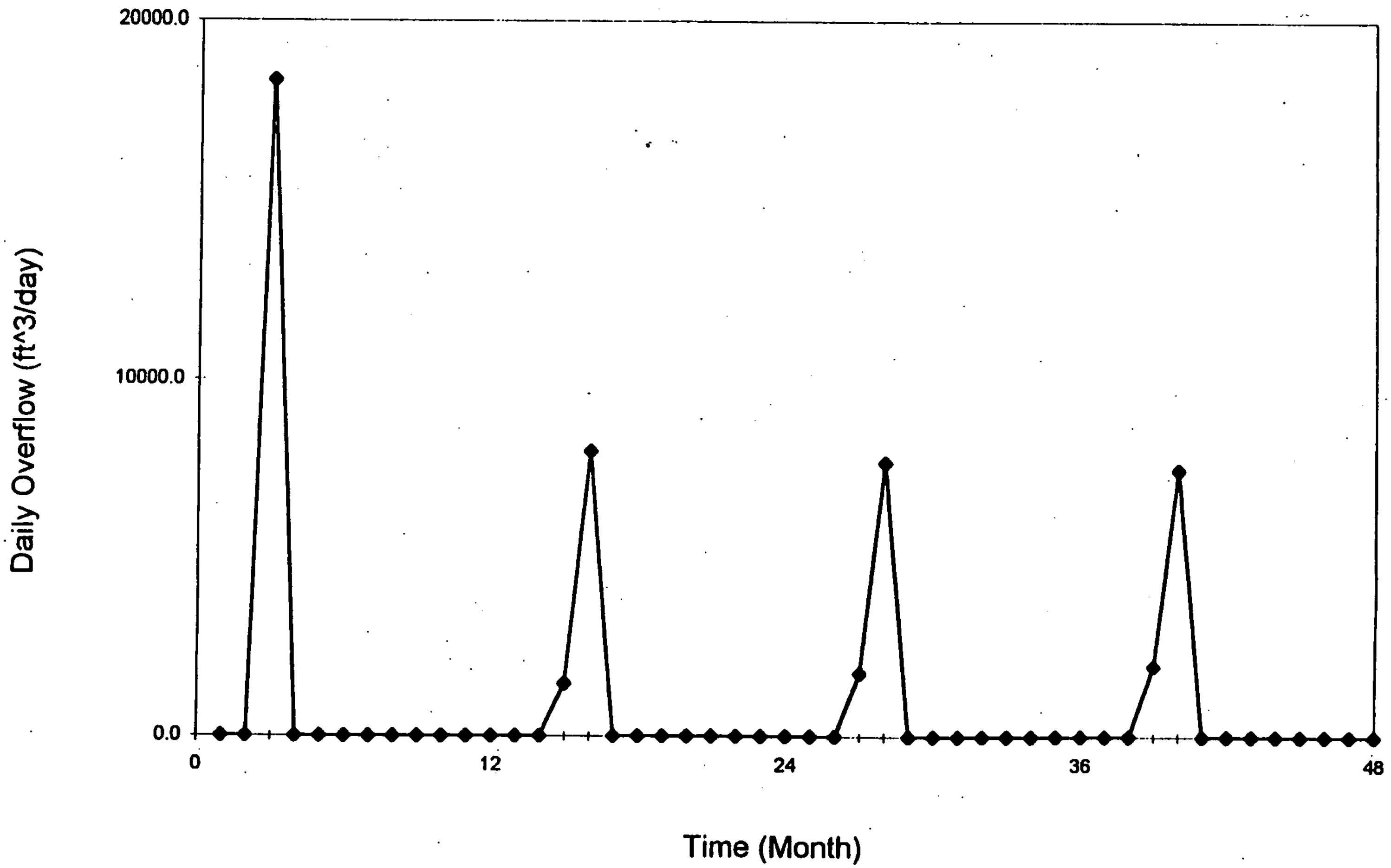

Figure 4-12 Daily Overflow Rates of Pond 1

255
256

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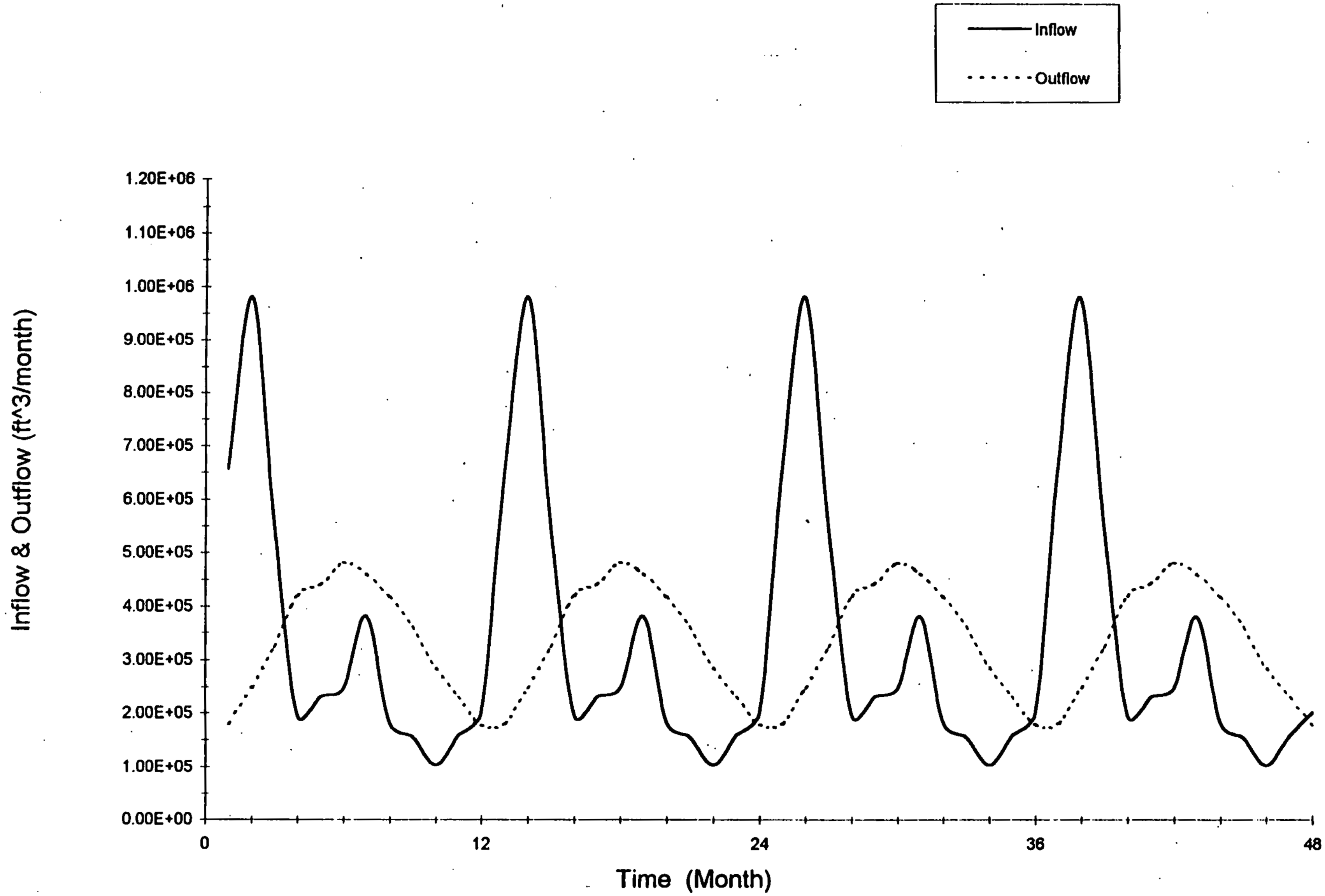

Figure 4-13 Monthly Inflow And Outflow Rates of Pond 2

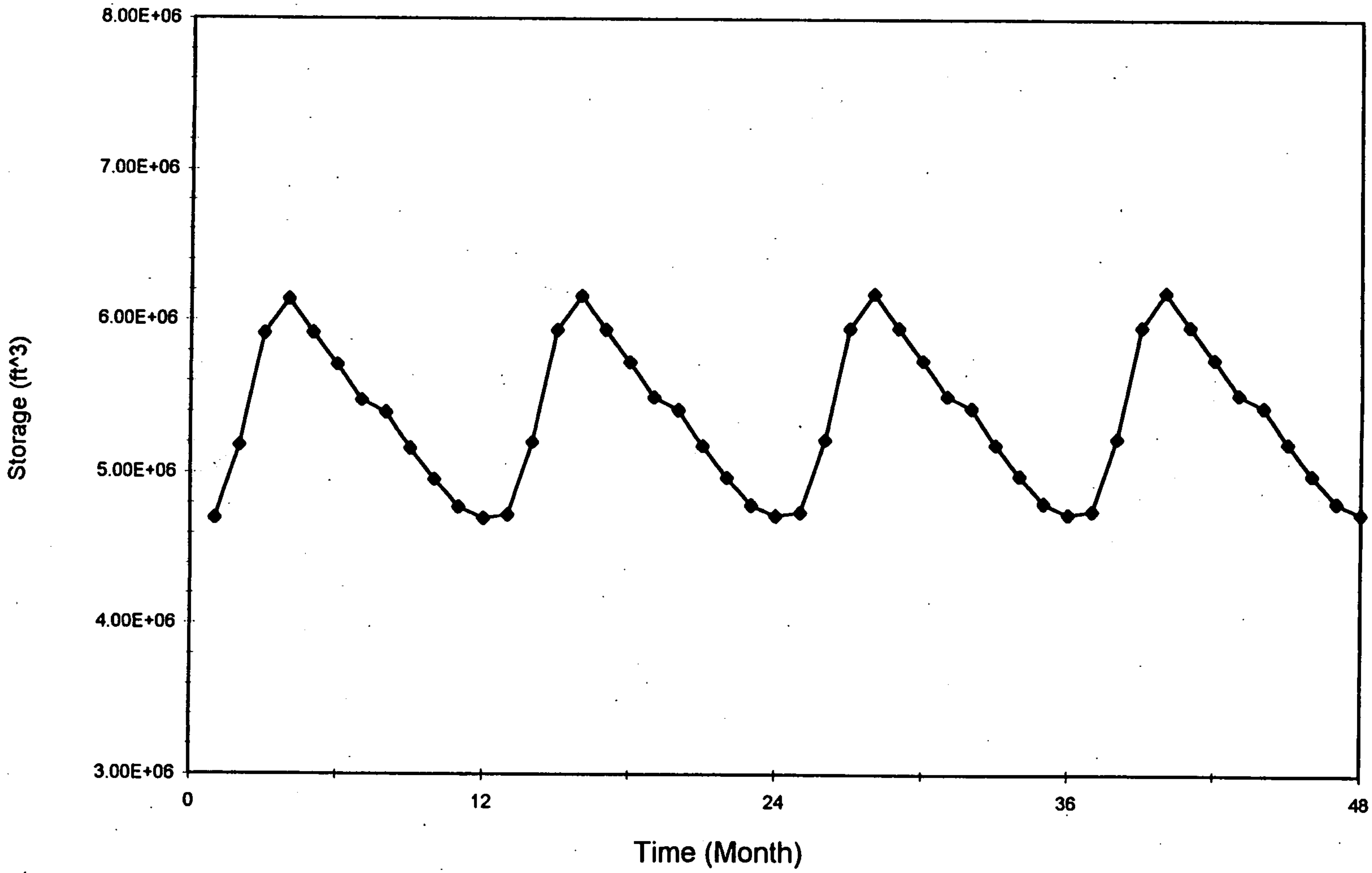

Figure 4-14 Monthly Storage Variations of Pond 2

257

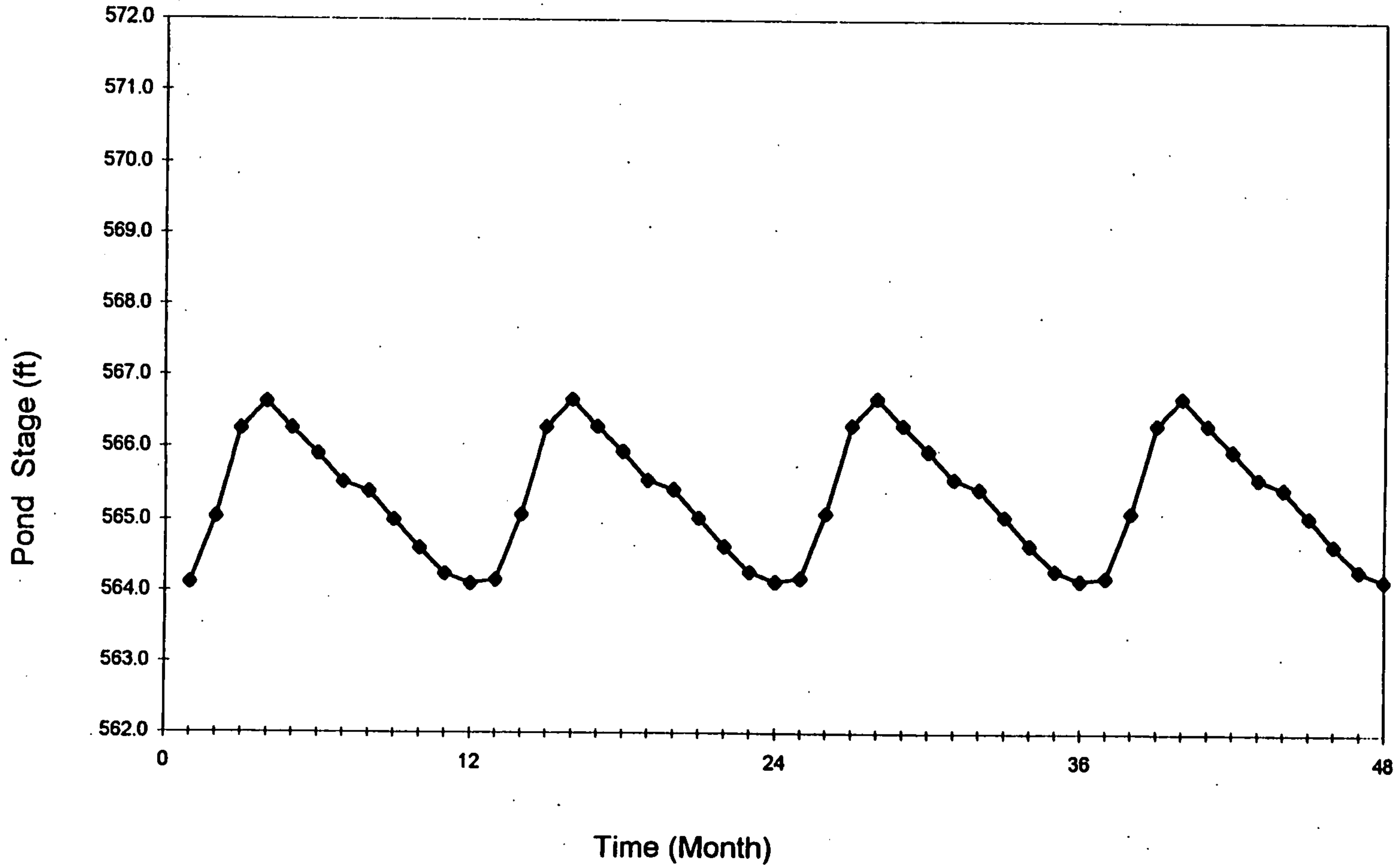

Figure 4-15 Monthly Stage Variations of Pond 2

258

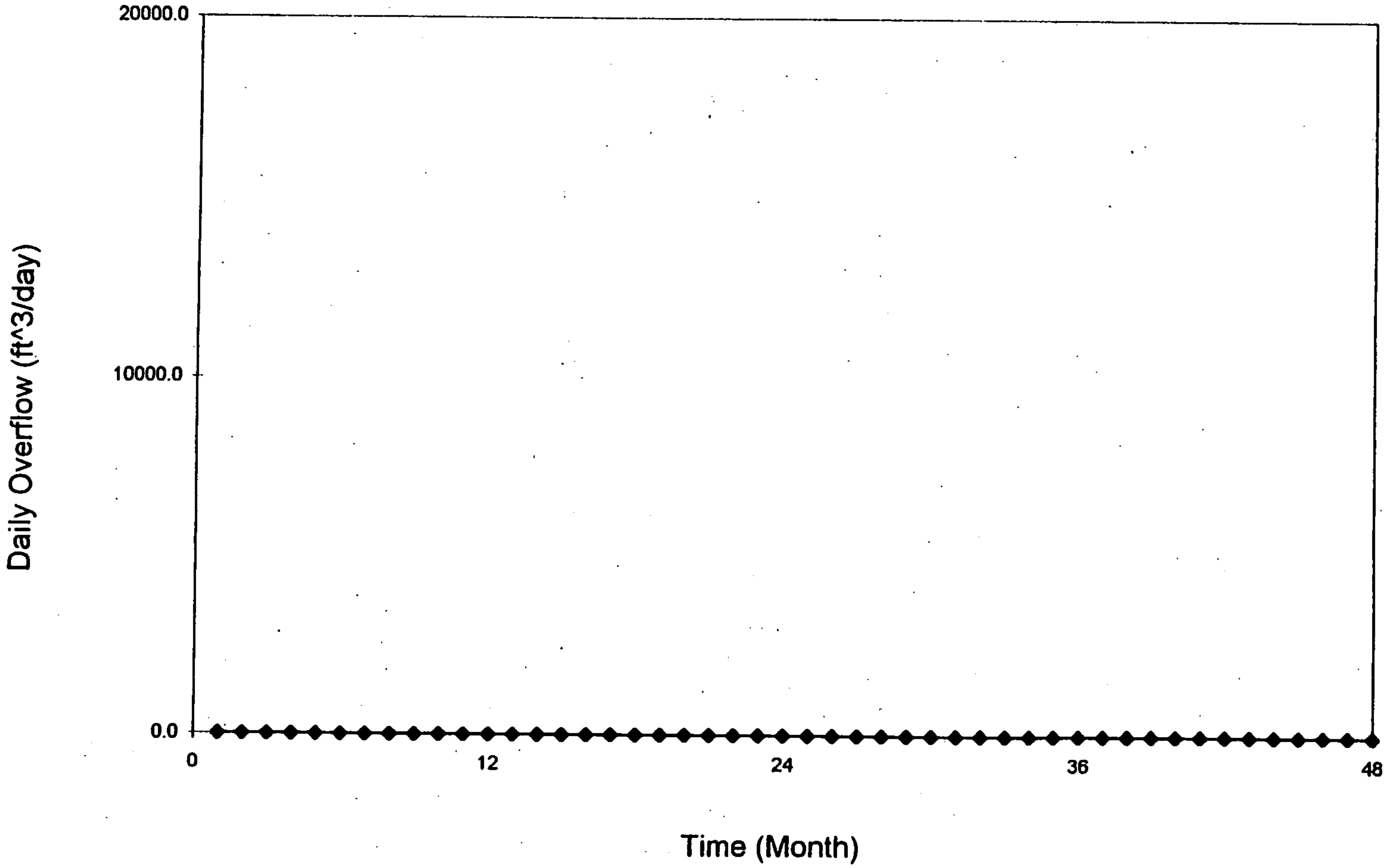

Figure 4-16 Daily Overflow Rates of Pond 2

259

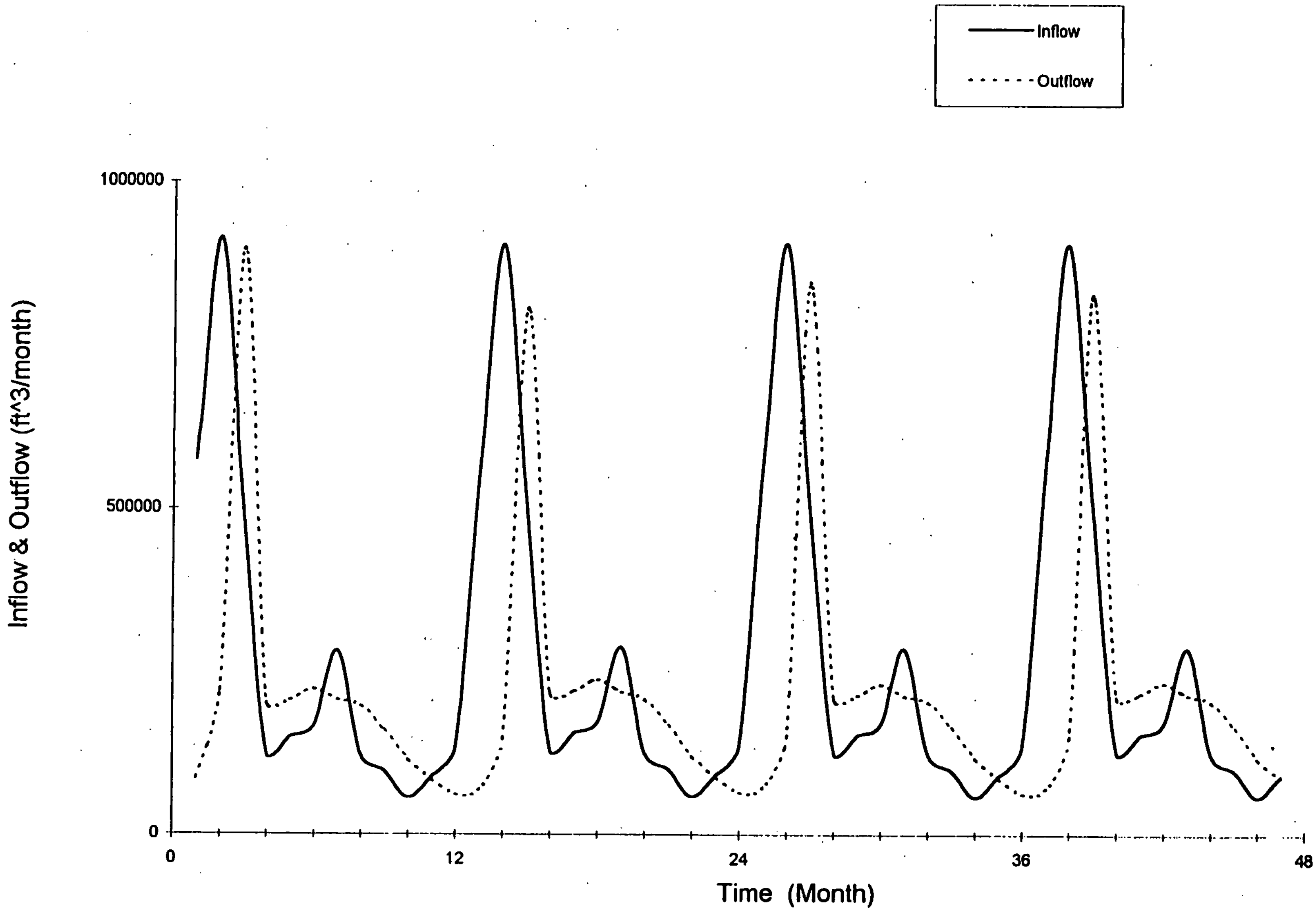

Figure 4-17 Monthly Inflow And Outflow Rates of Pond 3

260

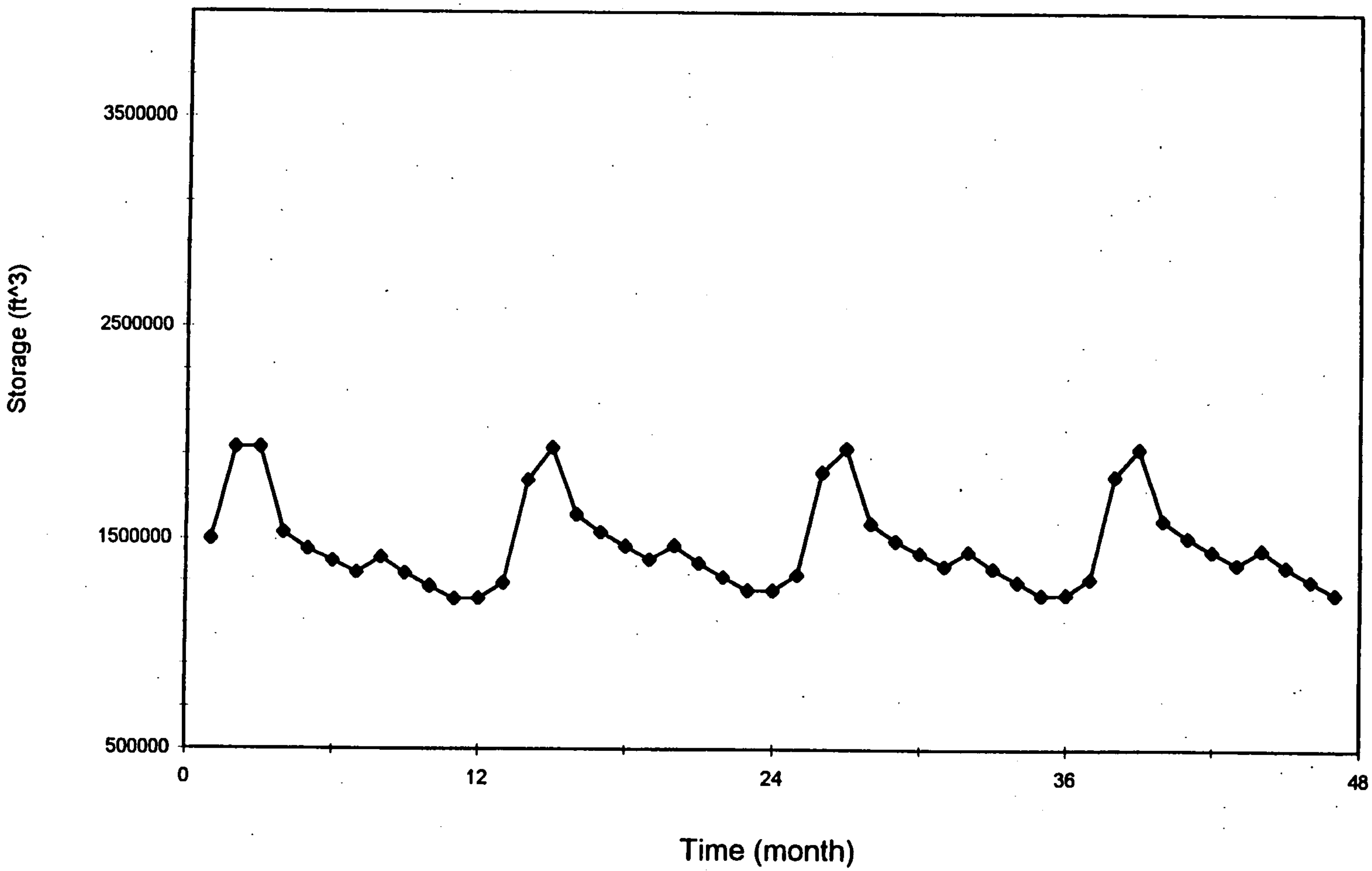

Figure 4-18 Monthly Storage Variations of Pond 3

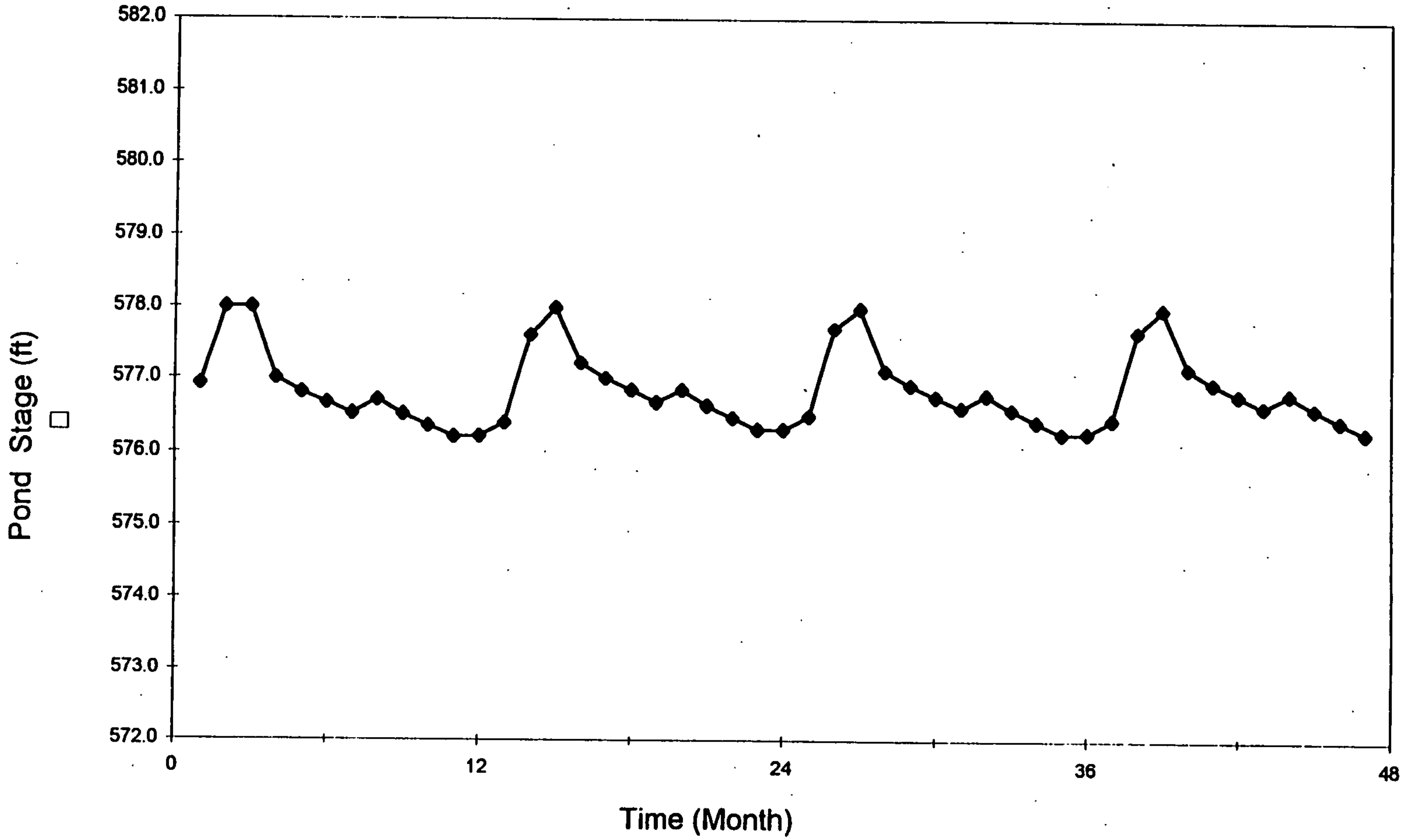

Figure 4-19 Monthly Stage Variations of Pond 3

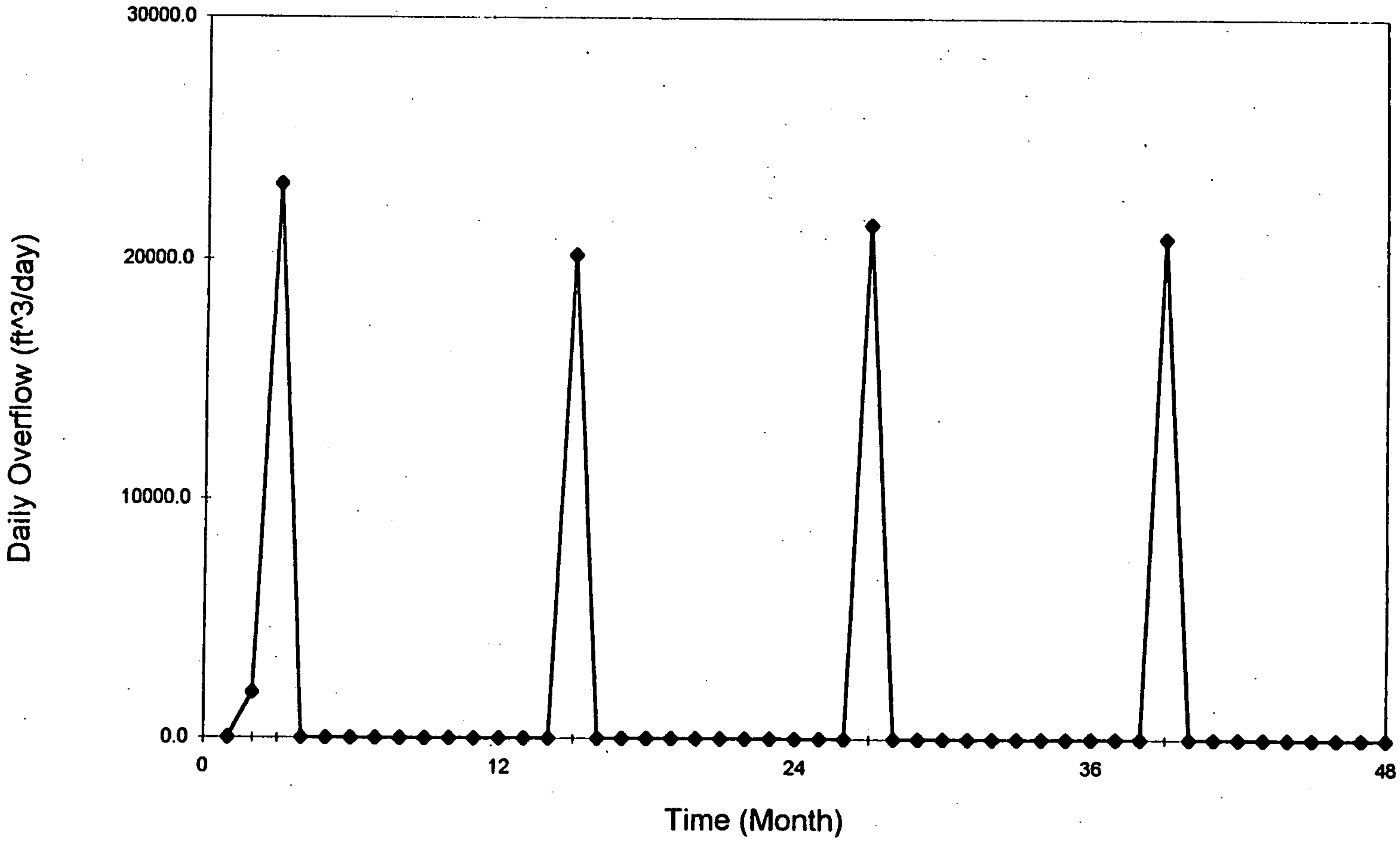

Figure 4-20 Daily Overflow Rates of Pond 3

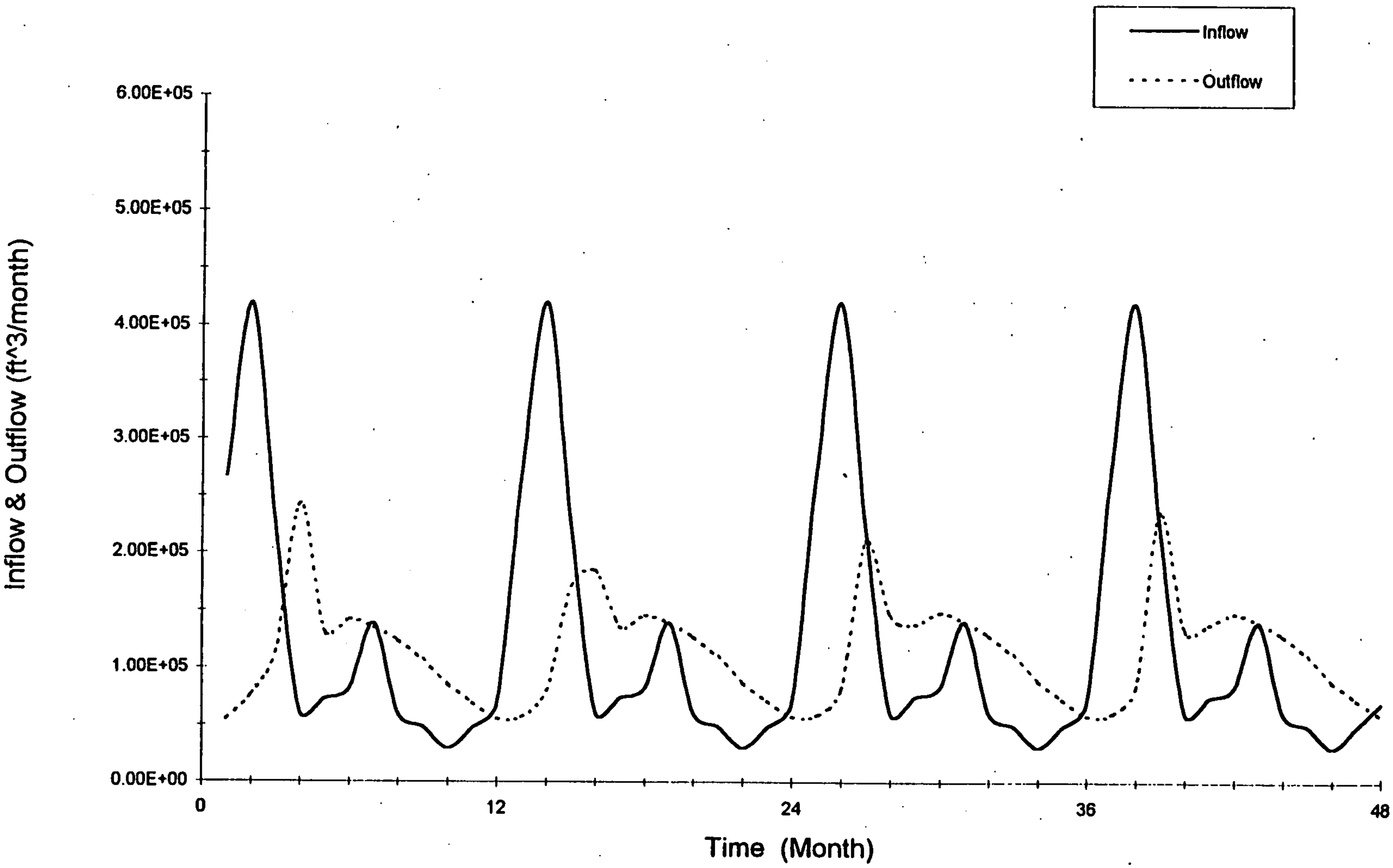

Figure 4-21 Monthly Inflow And Outflow Rates of Pond 4

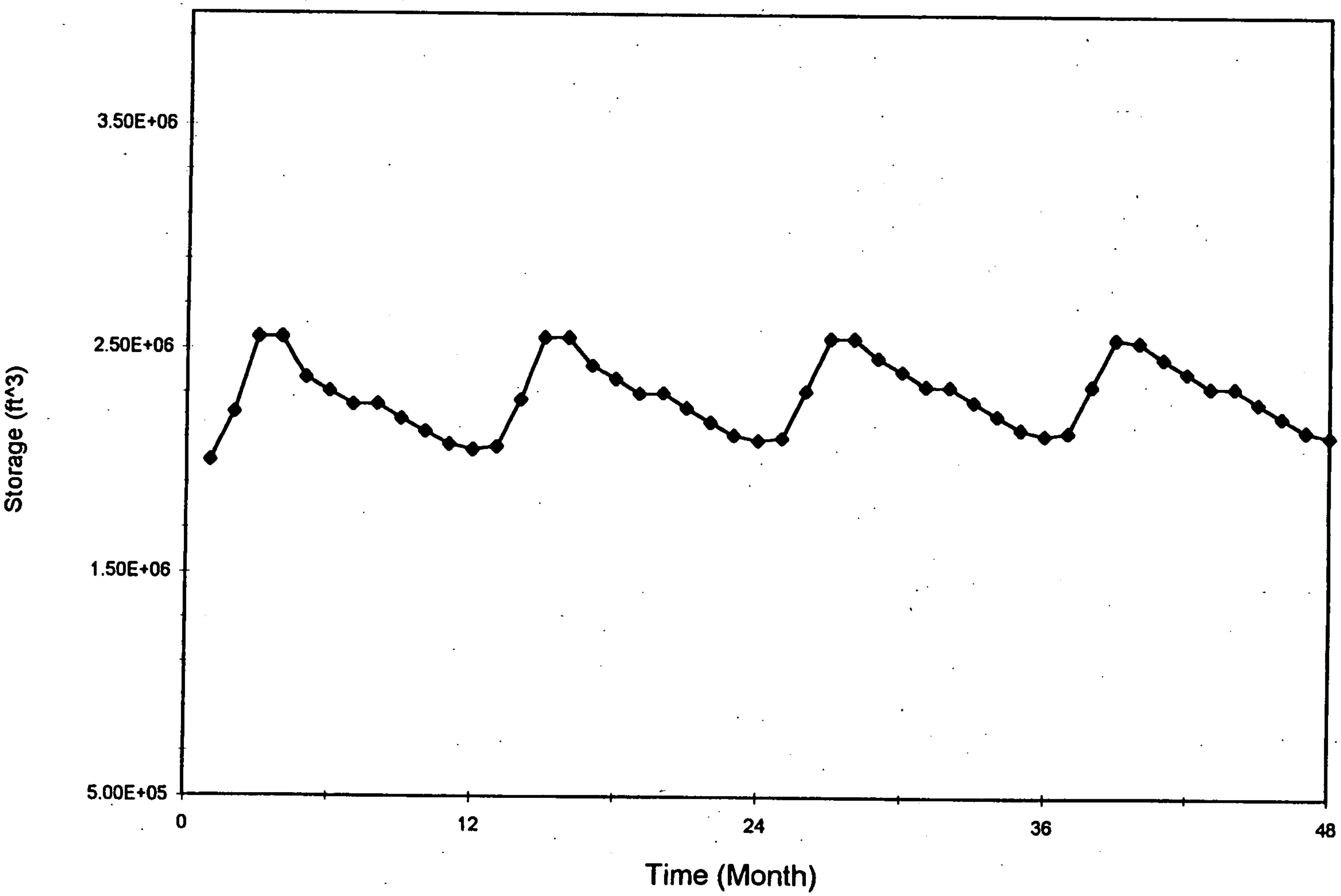

Figure 4-22 Monthly Storage Variations of Pond 4

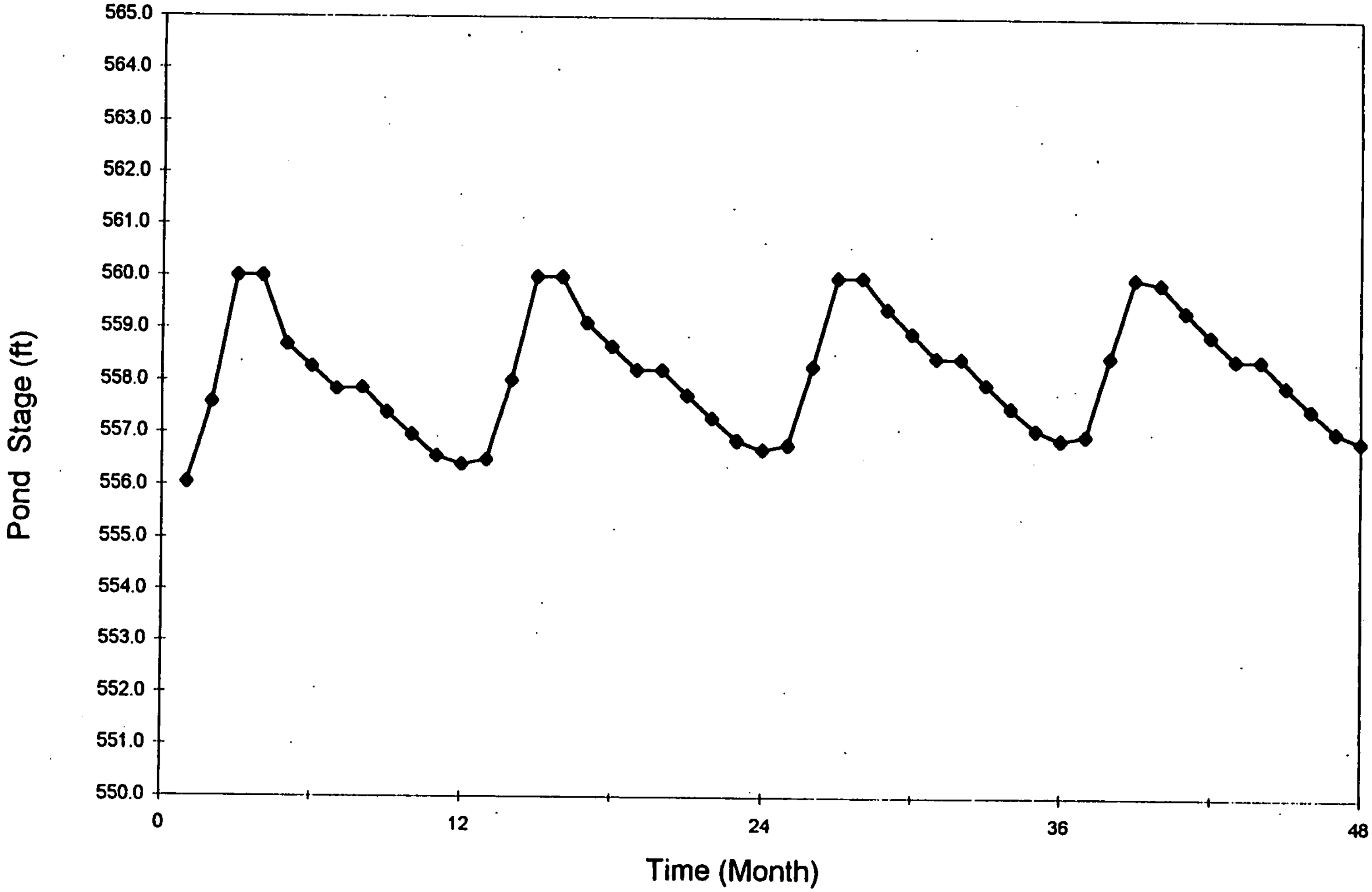

Figure 4-23 Monthly Stage Variations of Pond 4

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267

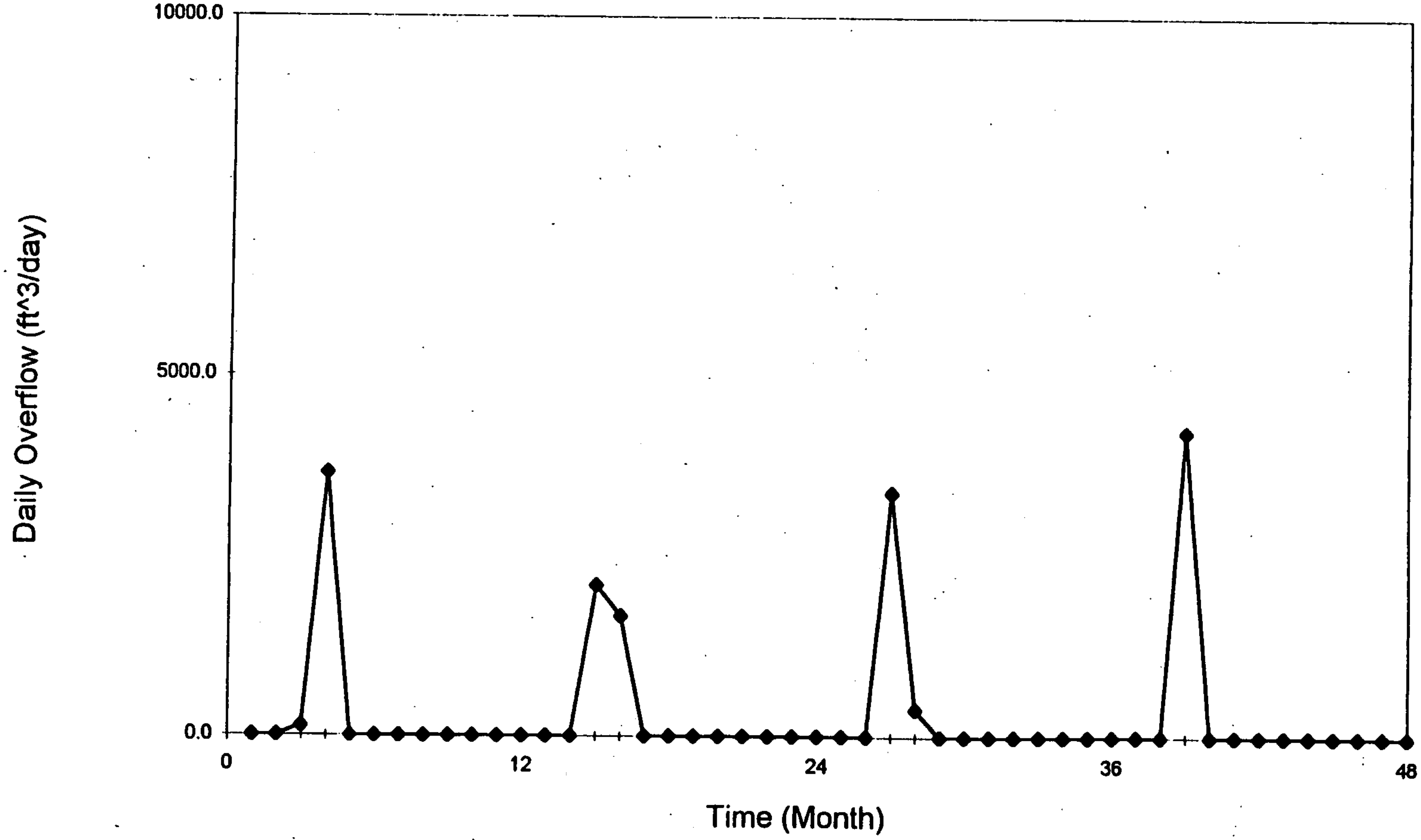

Figure 4-24 Daily Overflow Rates of Pond 4

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5.0 POND MODELING RESULTS UNDER EXTREME CONDITIONS

This section presents the storage routing modeling results under extreme conditions. The extreme conditions can be simulated by a storm event. The peak inflow rates generated by a storm event were modeled by using the TR55 method that is suitable for small watersheds. The characteristic storm typically considered in the TR55 method is a storm with a 25-year return period and a 24-hour duration. The input parameters and a brief description of inflow runoff routing using the TR55 method will be given first, then followed by the summary of modeling results generated by this characteristic storm.

5.1 INPUT PARAMETERS

The input data to the routing model used for the extreme conditions are briefly summarized in this subsection.

Drainage Area. The drainage areas are the total of their corresponding multiple subbasins. The drainage areas used in the TR55 method are the same as the normal conditions. Table 2-1 presents the areas of the subbasins that contribute runoff to each individual pond. Appendix B also presents the drainage areas and subbasin areas.

The following four parameters used for extreme conditions are the same as that for normal conditions.

- Pond Bottom Elevations.
- Pond Overflow Elevations.
- Groundwater Elevation.
- Pond Liner Hydraulic Conductivity.

The outflow components such as evaporation and infiltration through the pond liner were not considered in the routing process. The reason for this simplification is justified by the insignificant amount of loss of these two components within a relatively short period of the routing process (about three to five days).

Curve Number. A CN value of 74 was selected, based on site watershed hydrological soil groups.

25-year, 24 hour Rainfall Depth. A total of 4.7 inches of precipitation was selected from the Rainfall Frequency Atlas of the United Stated, TP No. 40.

Two-year, 24-hour Rainfall Depth. A total of 2.9 inches of precipitation was selected from the Rainfall Frequency Atlas of the United Stated, TP No. 40.

Other input parameters used in the TR55 method for characterizing the subbasins are Manning's roughness coefficient, land slope, flow length and flow width, and natural channel slope.. This data is also presented in Appendix B for each individual pond.

5.2 ROUTING HYDROGRAPH USING TR55 METHOD

Technical Release No. 55 (TR55), "Urban Hydrology for Small Watersheds," was originally developed by the United States Soil Conservation Service (SCS) in the 1970's, and was revised in 1986. TR55 was used to provide a hydrologic method for small watersheds. The Tabular Hydrograph Method is utilized for modeling multiple subareas that contribute runoff to one common design outfall point in a watershed. As a general guideline, the Tabular Hydrograph Method is applicable to a watershed with subbasin time of concentration between 0.1 and 2.0 hours, and subbasin travel time from 0.0 to 3.0 hours. For complicated watersheds, watersheds can be broken up into multiple subbasins such as the one shown in Figure 1-1. The effects of ground cover, time of concentration, reach routing times, drainage area, and precipitation for each subbasin can be taken into account independently first. Subsequently, it generates each subarea's runoff hydrograph and individually routes it to the watershed's outfall all in one step. All of the subarea's routed hydrographs are then summed directly at the watershed's outfall to obtain a composite hydrograph. Table 2-1 and Figure 1-1 presents the multiple subbasins that are related to their drainage areas.

5.3 POND INITIAL STAGES AND STORAGE

In order for the model to be conservative, the maximum storage volume predicted under normal conditions was used as the initial storage of the ponds, in addition to the peak discharge generated by a 25-year and 24-hour storm event. Table 5-1 presents the initial stage and corresponding storage of the four open water areas.

TABLE 5-1

POND INITIAL STAGES AND STORAGE

UNDER EXTREME CONDITIONS

	Stages (feet)	Storage (ft^3)
POND 1 (Northeast of FEMP)	573	$4.45x10^6$
POND 2 (Northwest of FEMP)	566.33	$5.96x10^6$
POND 3 (Southeast of FEMP)	578	$1.93x10^6$
POND 4 Retention Pond	560	$2.55x10^6$

As indicated in the above table, the initial stage of the four ponds are also the maximum stages designed for the normal conditions, since the weirs will facilitate outflow control. With the exception of Pond 2, the weir bottom elevations have set the maximum pool levels within the ponds.

Tables D-1 through D-4 in Appendix D present the storage routing calculations for a 25-year frequency and 24-hour duration storm.

5.4 POND INFLOW AND OUTFLOW HYDROGRAPH

TR55 method will generate a composite hydrograph for each pond given the physical and hydrologic parameters for the subbasins. The time step used in storage routing computation is six minutes. The input parameters used in TR55 method such as CN value and Mannings value for grassy condition are consistent with the OSDF surface water management study prepared by Parsons. A CN value of 74 was also selected, based on site watershed hydrological soil groups. The soil groups were classified as type B and C, for Dana Eden, Fincastle, Miamian-Russel, Ragsdale, and Xenia soils. A Mannings number of 0.3 was used for a dense bermude grass.

The results indicated that Pond 1 has the highest peak inflow rates of 129 cubic feet per second (cfs), while Pond 4 (retention pond) has a lowest inflow rates given the same characteristic storm event. This difference in peak inflow rates is directly affected by the size of their drainage areas. Table 5-2 presents the peak inflow rates and the time it takes to reach the peak inflow rates.

TABLE 5-2
PEAK INFLOW RATES AND TIME TO PEAK DISCHARGE UNDER EXTREME CONDITIONS

	Peak Inflow Rates (cfs)	Time to Peak Inflow Rates (hours)
POND 1 (Northeast of FEMP)	129	13
POND 2 (Northwest of FEMP)	117	13
POND 3 (Southeast of FEMP)	95	12.8
POND 4 (Retention Pond)	43	13.2

Figures 5-9, 5-13, 5-17, and 5-21 present inflow and outflow hydrographs for the four ponds respectively. As indicated in the hydrographs, outflow generated by this characteristic storm will generally takes 130 hours or about five days to be dissipated through the weirs. The weirs width were designed as five feet for Pond 1, 2, and 3. The weir bottom width for retention pond is 20 feet, based on the exiting configurations.

5.5 POND STORAGE VARIATION WITH TIME

Figures 5-10, 5-14, 5-18, and 5-22 present pond storage variations with respect to time for the four ponds respectively. Time to reach the peak inflow rates ranged from 12.8 to 13.2 hours (also see Table 5-2). As indicated in the hydrograph, storage variations experienced within each pond are in the same order of magnitude. This is the result of regulation through the weirs. Table 5-3 presents the storage changes for each pond.

TABLE 5-3

MAXIMUM AND MINIMUM POND STORAGE UNDER EXTREME CONDITIONS

	Maximum Storage (ft^3)	Minimum Storage (ft^3)
POND 1 (Northeast of FEMP)	$4.99x10^6$	$4.45x10^6$
POND 2 (Northwest of FEMP)	$6.77x10^6$	$5.96x10^6$
POND 3 (Southeast of FEMP)	$2.36x10^6$	$1.93x10^6$
POND 4 (Retention Pond)	$2.67x10^6$	$2.55x10^6$

5.6 POND STAGE VARIATIONS WITH TIME

Figures 5-11, 5-15, 5-19, and 5-23 present stage variations with respect to time for the four ponds respectively. The time required to reach the peak stage are the same as that for the storage cases (Table 5-2). Figures 5-1, through 5-8 present the pond water surface outline for the four ponds. As indicated in the figures, stage variations experienced in Pond 1 is wider when compared to the other three ponds. This is due to the relatively smaller water storage, but with larger drainage area. Table 5-4 presents the stage changes for each pond. Pond 2 has a higher storage capacity, since it has a smaller drainage area, but will be excavated more extensively during the soil remediation. The purpose of Pond 3 is for a temporary runoff storage. Stormwater can be freely overflowed through a weir to SSOD. Of the four ponds, Pond 4 is the smallest one. Pond 4 can also be functioned as an intermediate retention basin prior to being overflowed to the SSOD. As indicated in Table 5-4, a hydraulic connection between Pond 1 and Pond 2 would physically combine Pond 1 and Pond 2 into one pond with higher storage capacity .

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TABLE 5-4

MAXIMUM AND MINIMUM POND STAGE UNDER EXTREME CONDITIONS

FEMP - POST EXCAVATION CONDITION

	Pond Stage		**Pond Top Edge Elevation (feet)**
	Maximum (feet)	Minimum (feet)	
POND 1 (Northeast of FEMP)	574.05	573.0	575
POND 2 (Northwest of FEMP)	567.67	566.3	575
POND 3 (Southeast of FEMP)	579.06	578.0	580
POND 4 Retention Pond	560.51	560.0	575

5.7 MAXIMUM AND AVERAGE DEPTH AND ACERAGE OF THE PONDS

The maximum and average depths of the ponds were estimated for each time step during the entire length of routing process. As described in Section 4.0, the maximum depth was computed as the difference between the water surface elevation and the pond bottom elevation. The average depth was determined by the ratio of the average storage and the average surface water area. Figures 5-12, 5-16, 5-20, and 5-24 present the maximum and average water depths under extreme conditions. As indicated in the figures, maximum and average water depths reach the highest when the peak inflow rates occur (about 13.0 hours). The time it takes to reach the peak inflow rates is presented in Table 5-2. The maximum water depths estimated for the four ponds, when the peak inflow rates appear are approximately 19.05, 17.67, 14.06, and 25.51 feet respectively. At the same time, the average water depths estimated for the four ponds are 8.41, 10.65, 4.24, and 14.85 feet respectively. The corresponding maximum water surface acreage computed for the four ponds are 13.34, 14.0, 12.9, and 4.12 acres respectively. Also, the average water surface acreage computed for the four ponds are 13.03, 13.85, 12.0, and 4.02 13.03, 13.85, 12.0, and 4.02 acres respectively.

5.8 CONNECTION CHANNEL DIMENSION

Trapezoidal channels with grass were proposed for the conveyance of overflowed stormwater. The channels bottom width are three feet, with side slope of 1V:1H. The Manning's roughness used was 0.3 for a natural channel with grass and stones. The slope of channel was estimated as 0.1 percent. The corresponding discharge rates and water depth in the channel were 18 cfs and 2.1 feet respectively. The calculated velocity was1.3 feet/sec, which is considered as subcritical flow.

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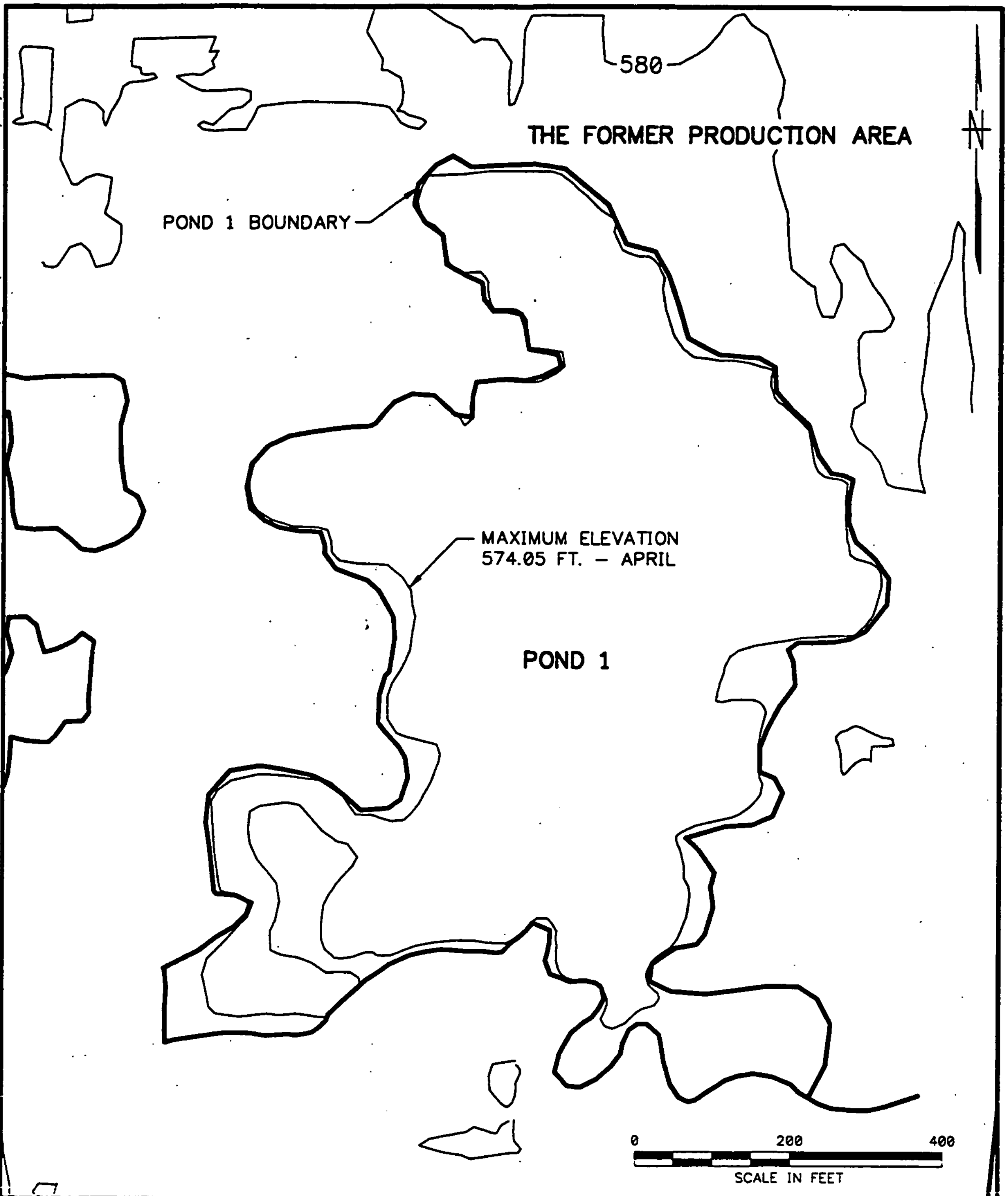

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CHECKED BY / DATE	POND 1 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MAXIMUM ELEVATION FEMP	APPROVED BY / DATE	
COST/SCHED-AREA		APPROVED BY / DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 5-1	REV. 0

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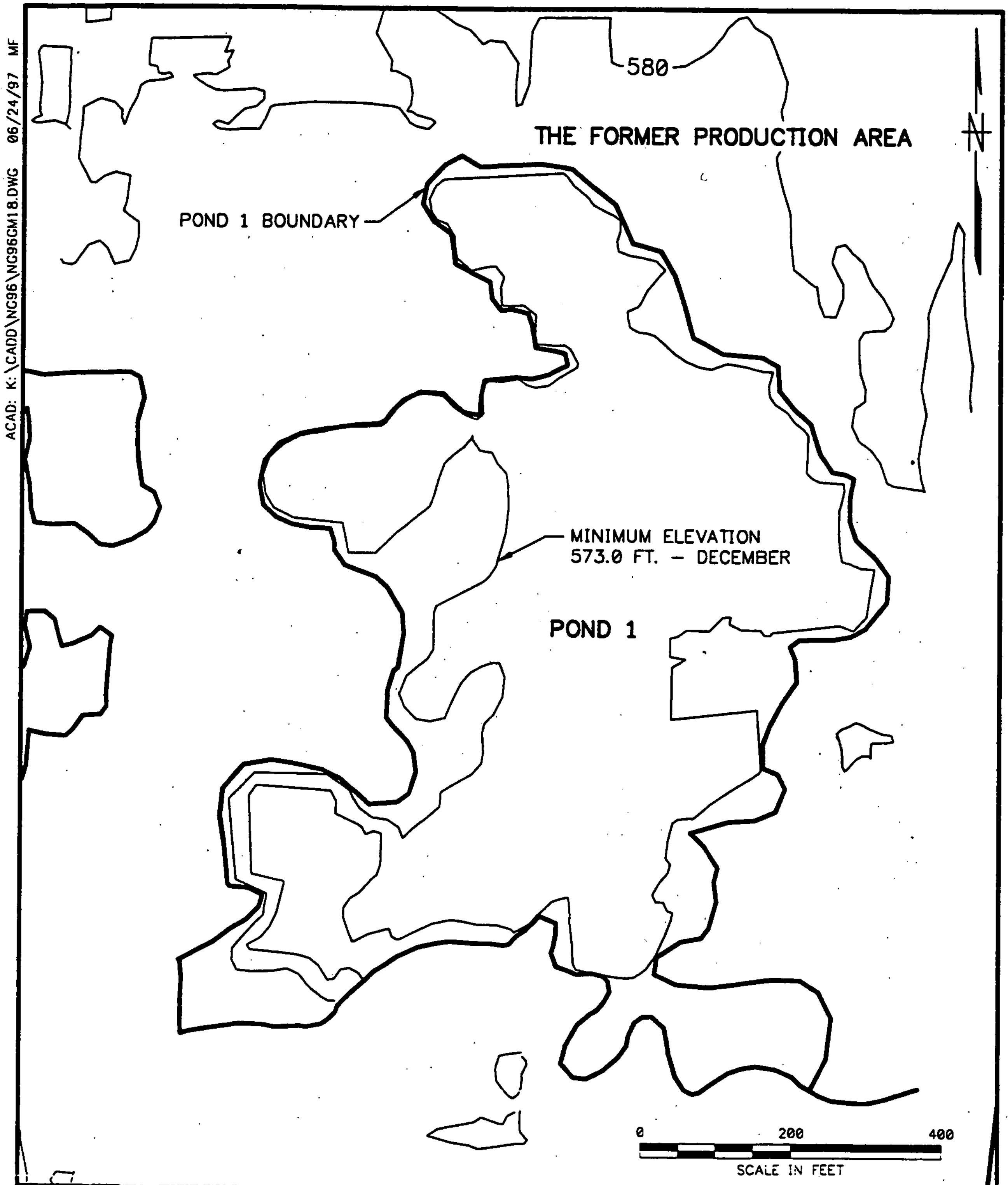

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COST/SCHED-AREA		APPROVED BY / DATE	
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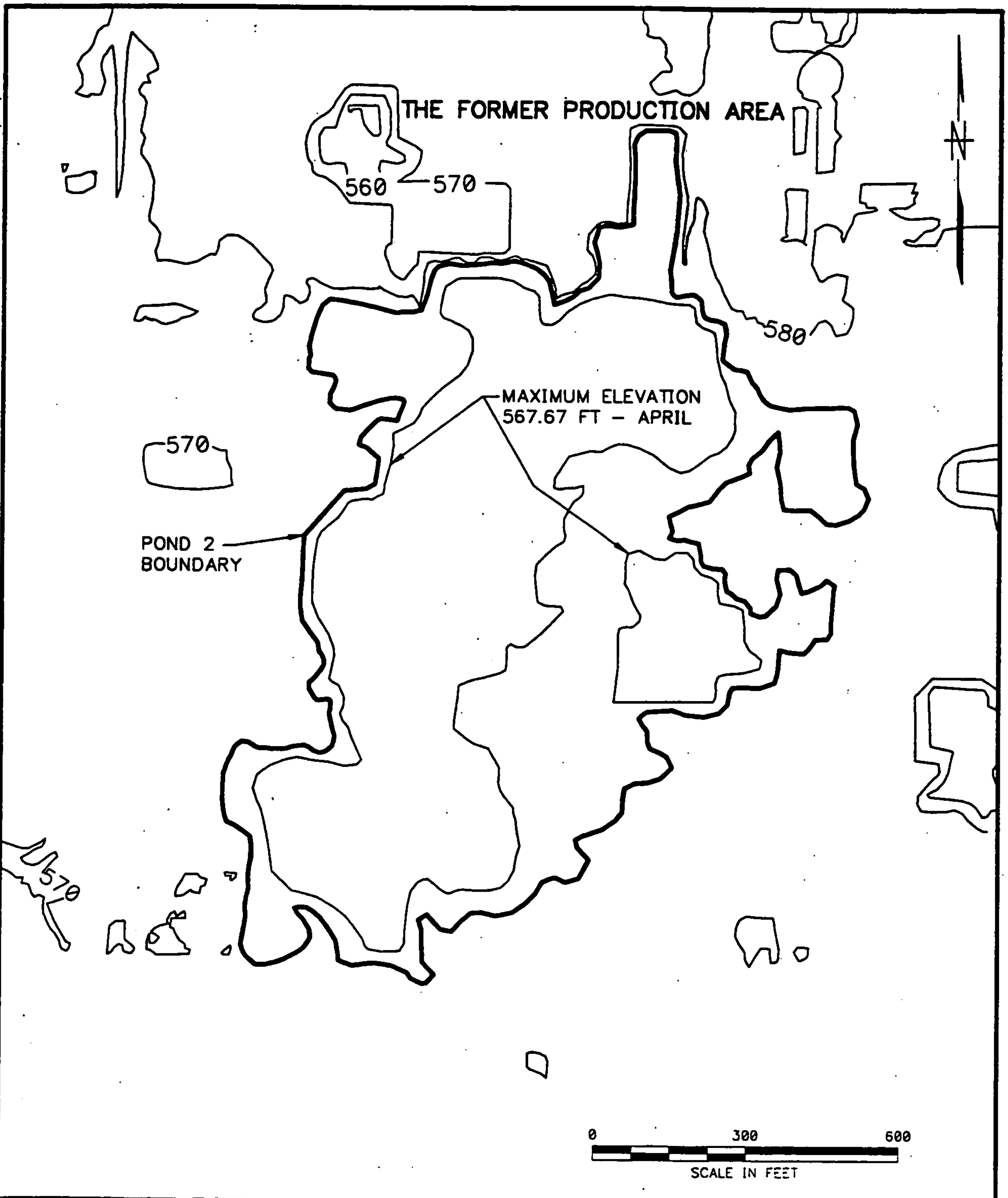

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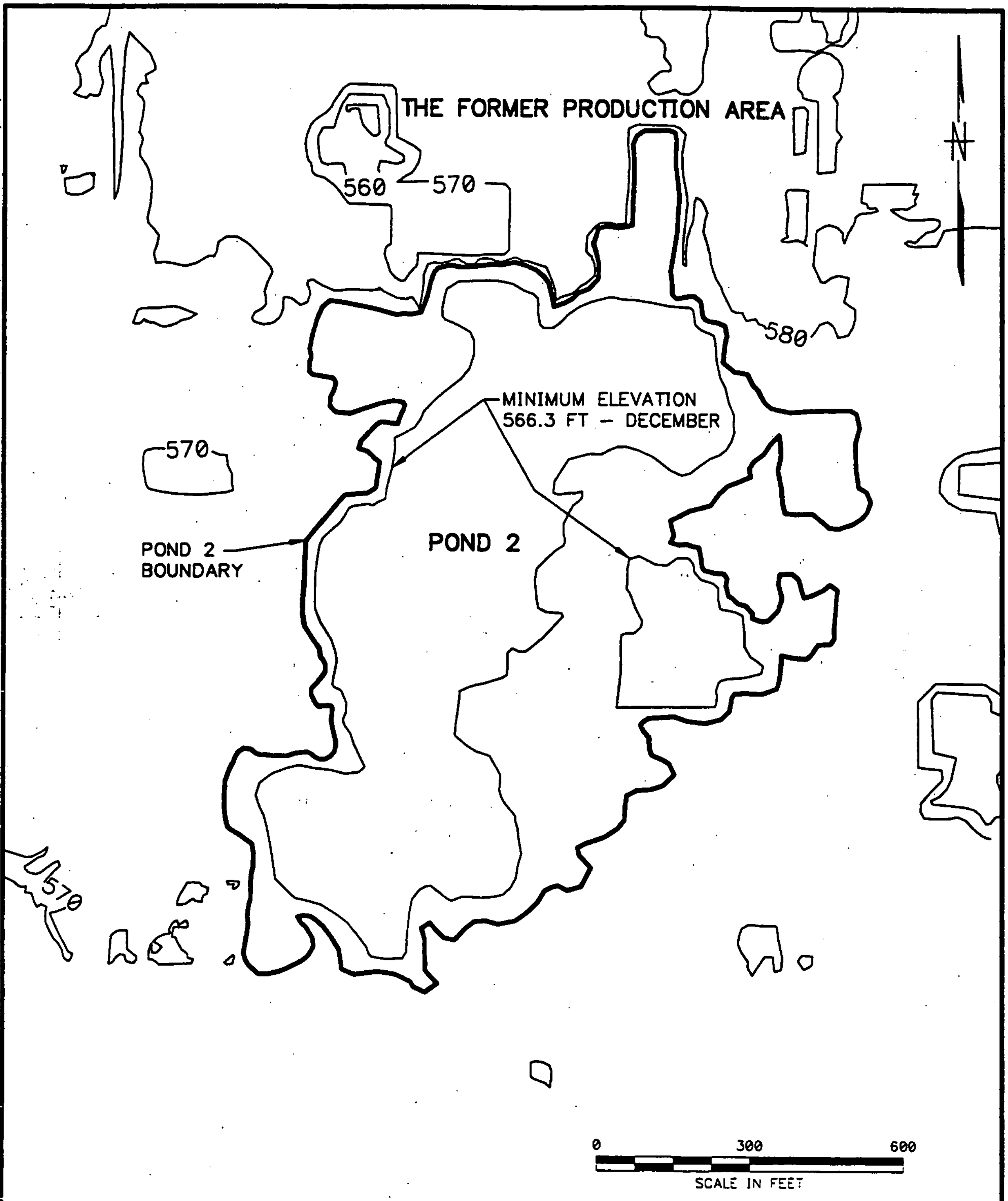

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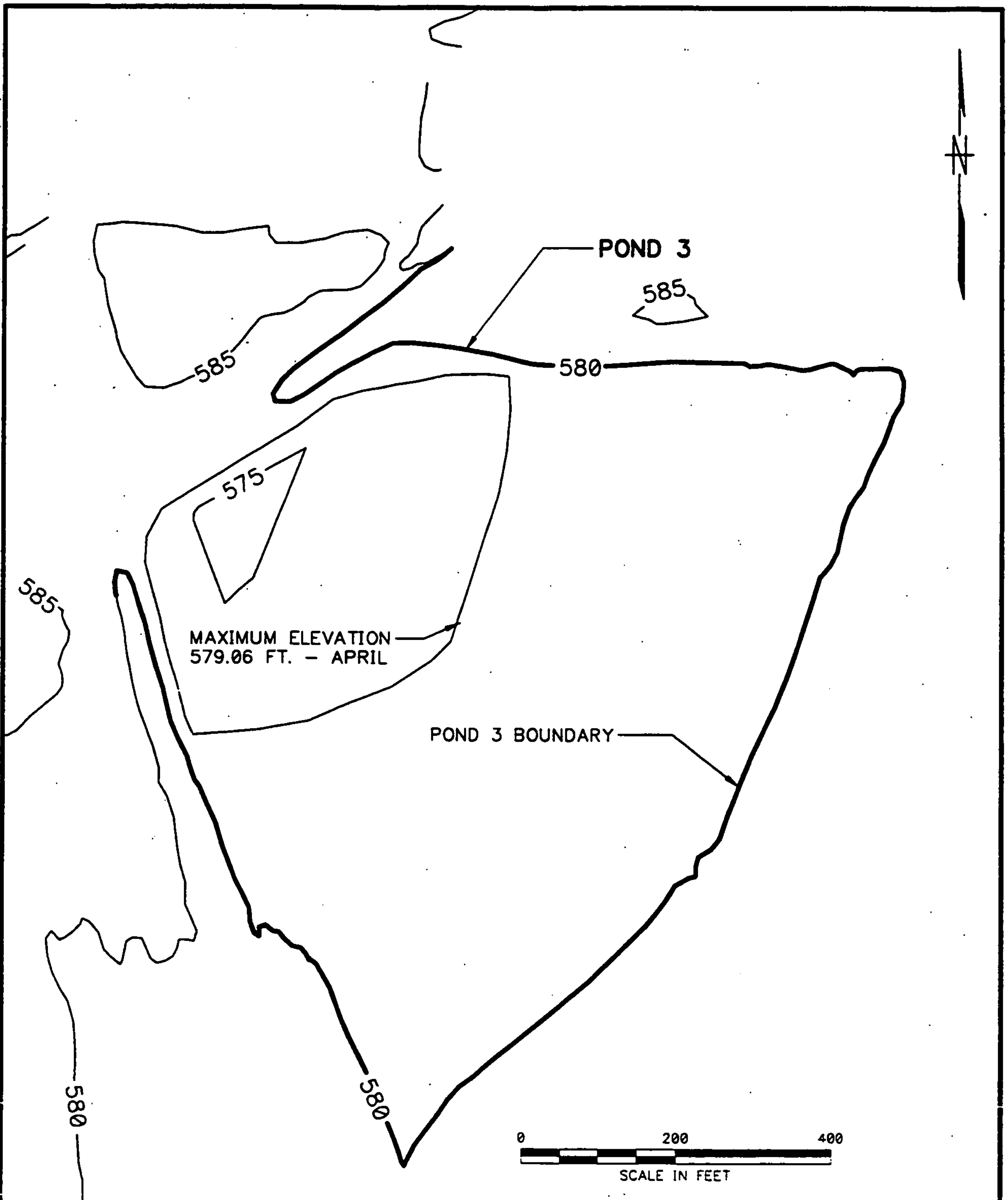

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COST/SCHED–AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 5–5	REV. 0

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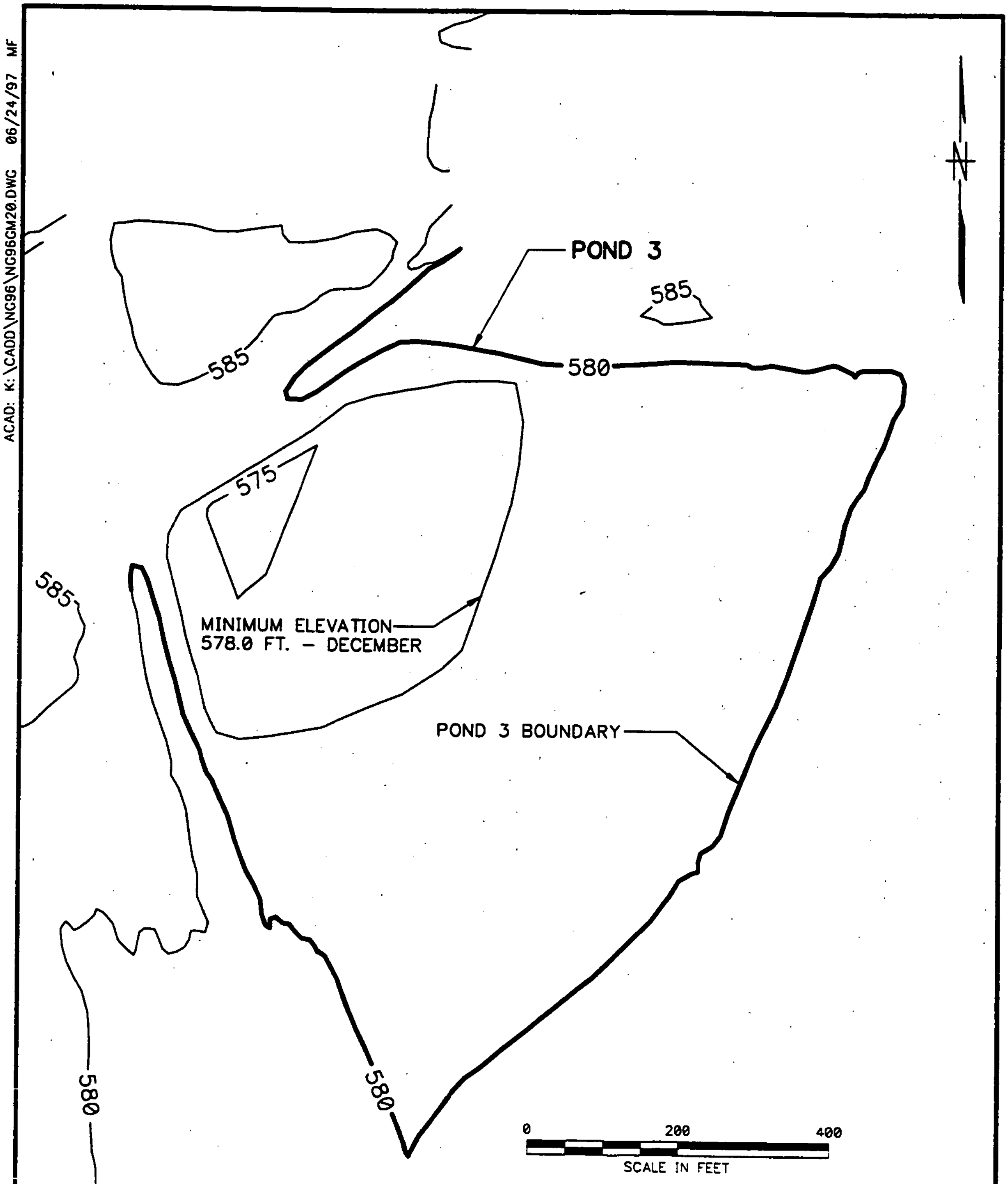

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COST/SCHED-AREA			APPROVED BY	DATE
SCALE AS NOTED			DRAWING NO. FIGURE 5–6	REV. 0

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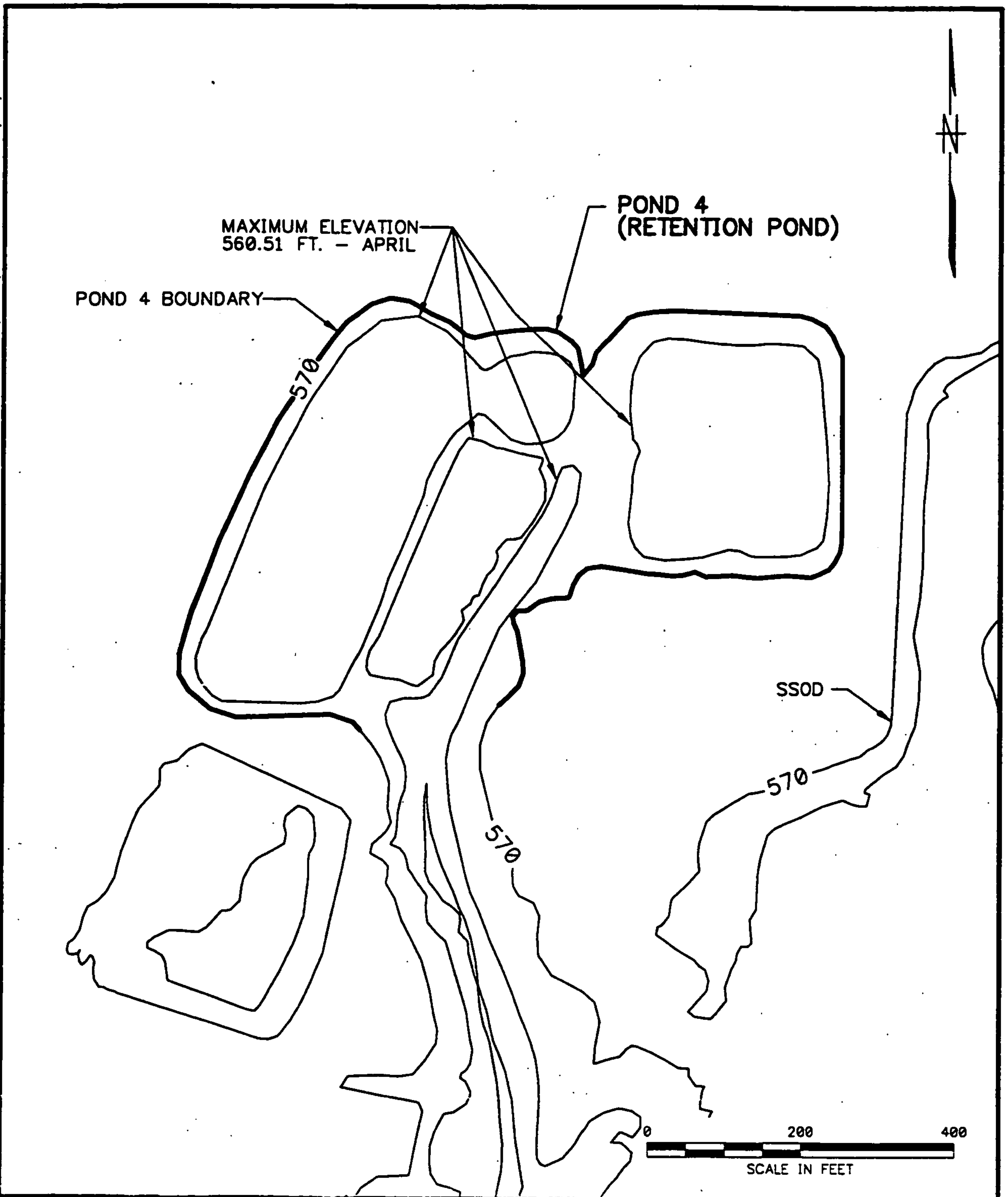

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-7	REV. 0

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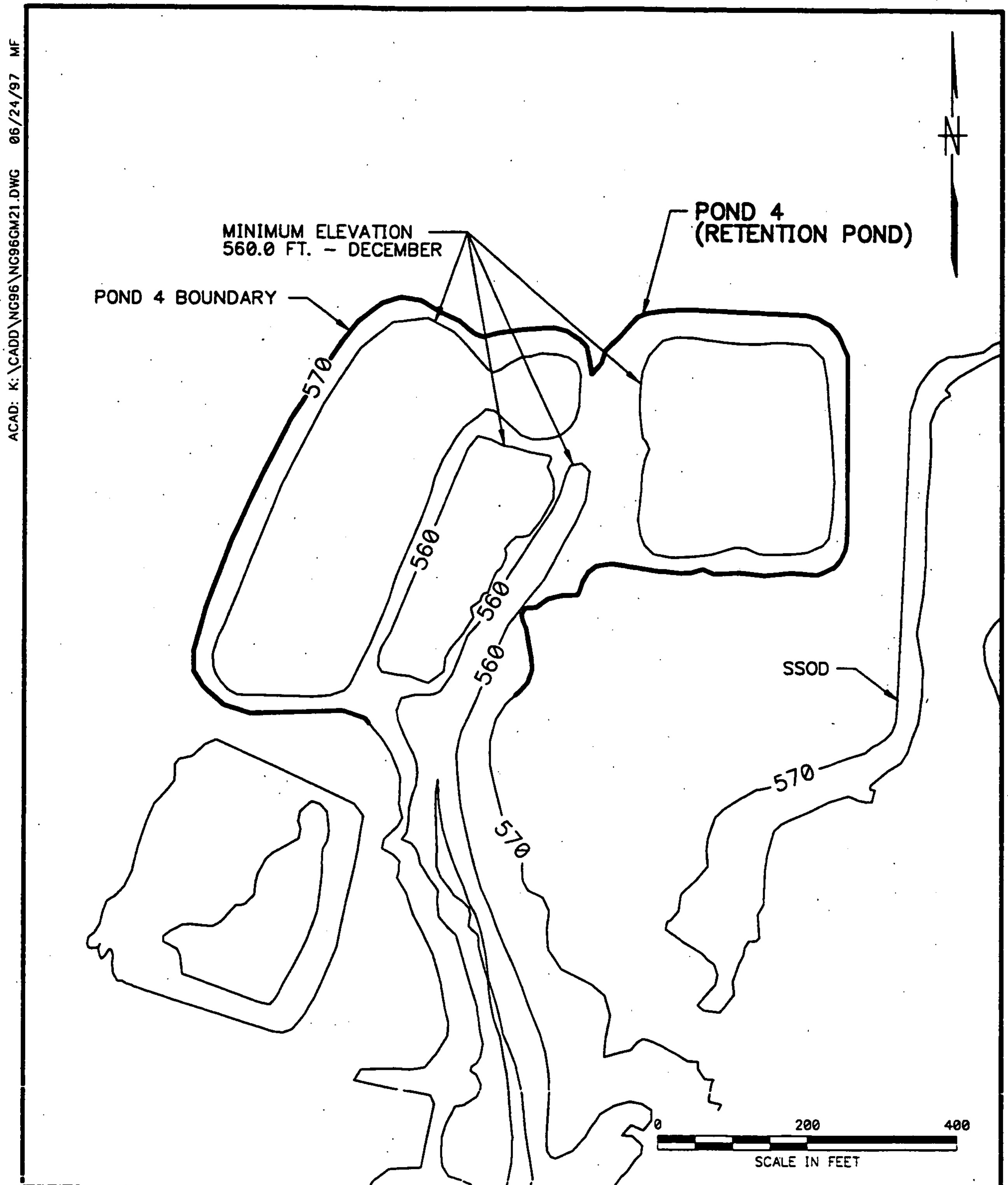

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COST/SCHED-AREA			APPROVED BY	DATE
SCALE AS NOTED			DRAWING NO. FIGURE 5-8	REV. 0

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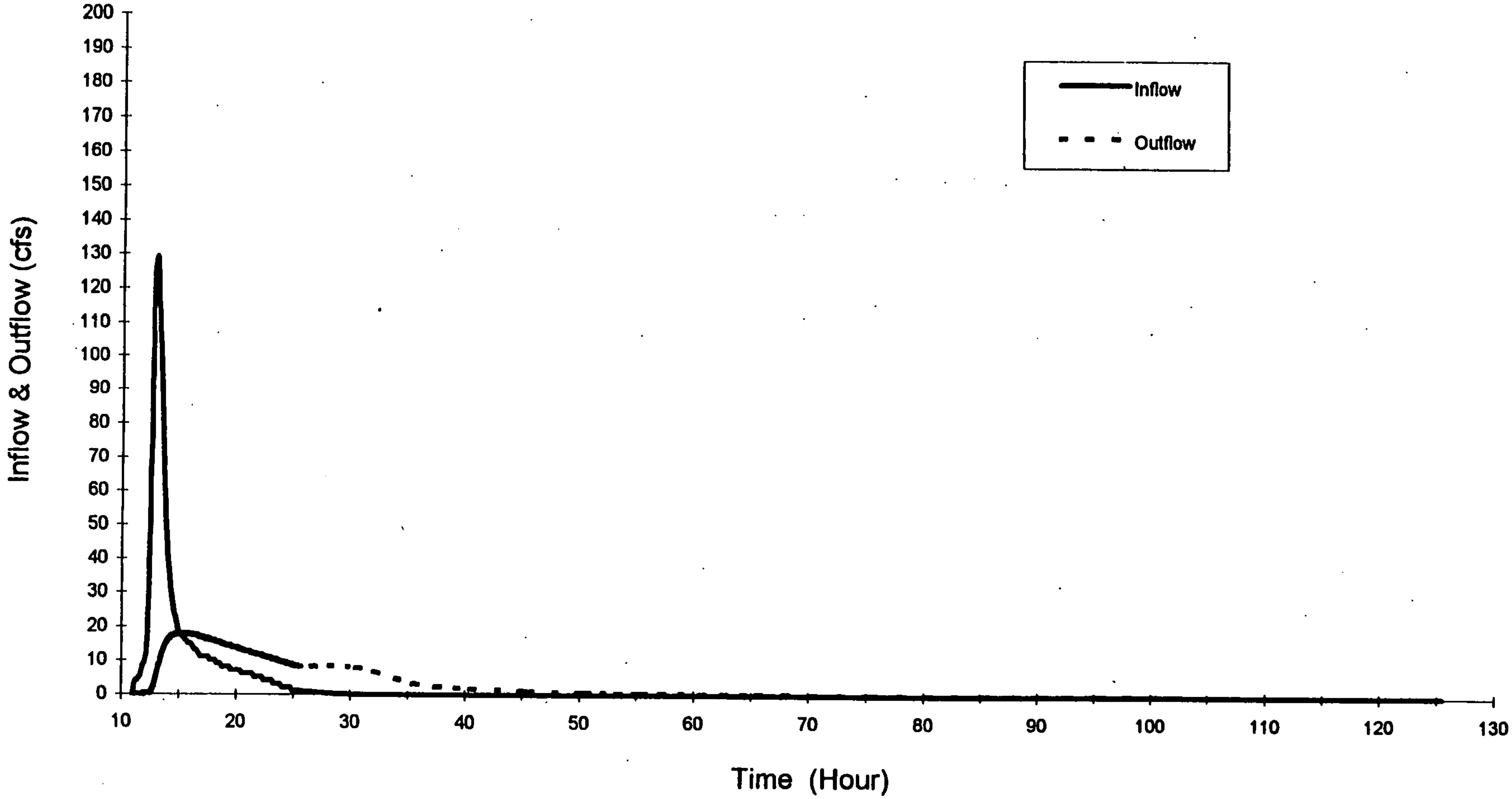

Figure 5-9 Inflow And Outflow Rates of Pond 1 Under Extreme Conditions

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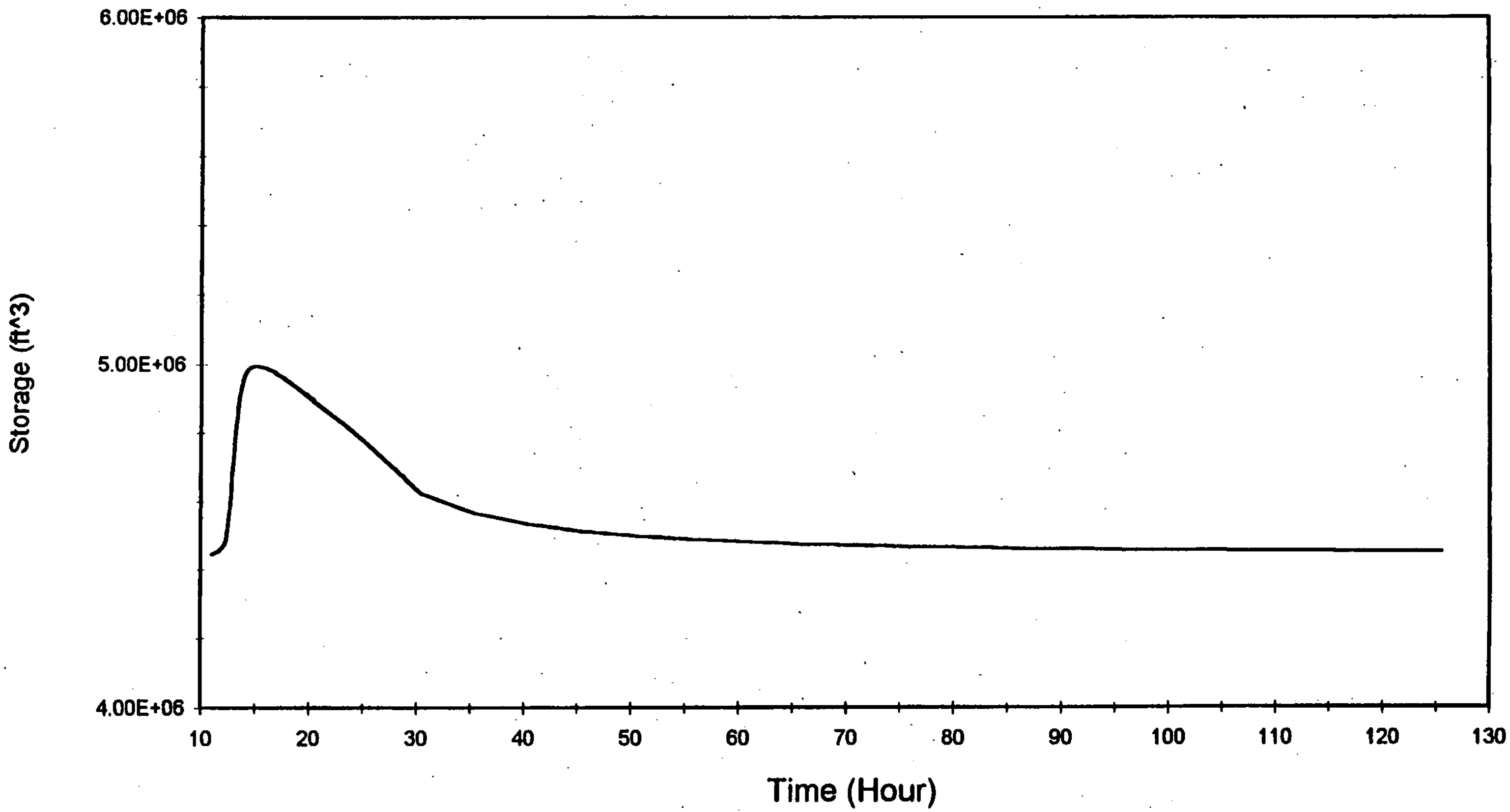

Figure 5-10 Storage Variations of Pond 1 Under Extreme Conditions

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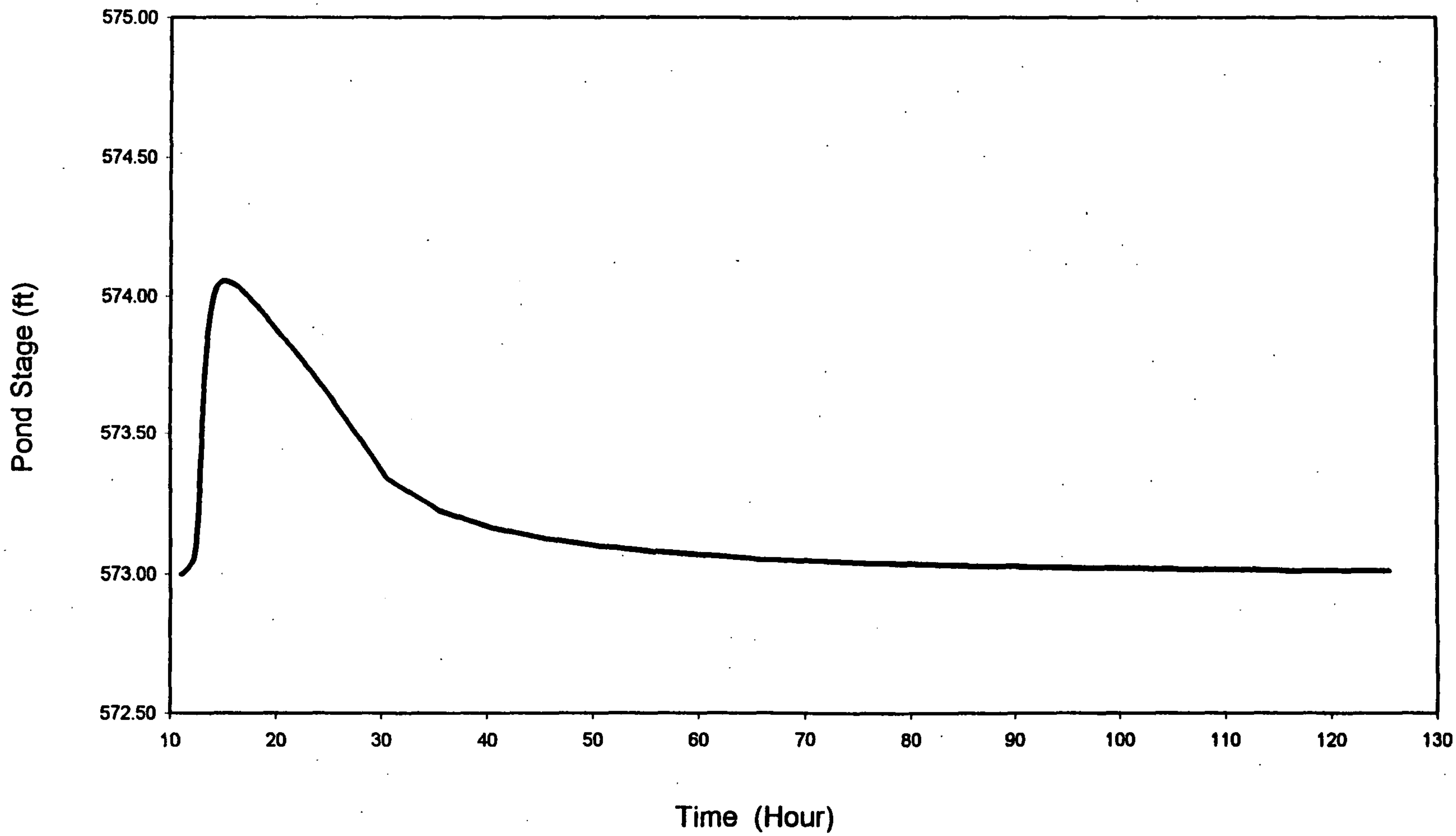

Figure 5-11 Stage Variations of Pond 1 Under Extreme Conditions

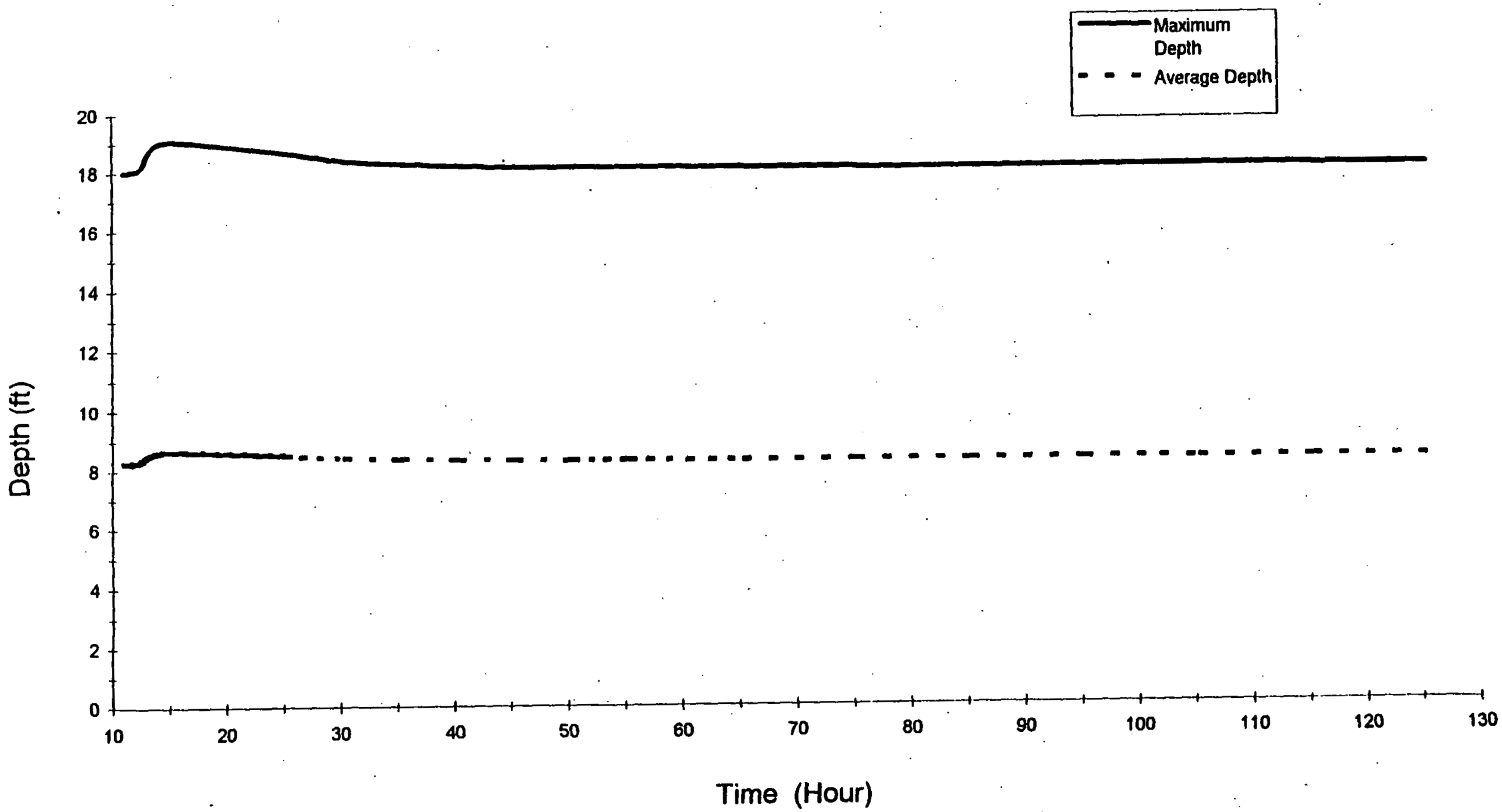

Figure 5-12 Maximum and Average Depth of Pond 1 Under Extreme Conditions

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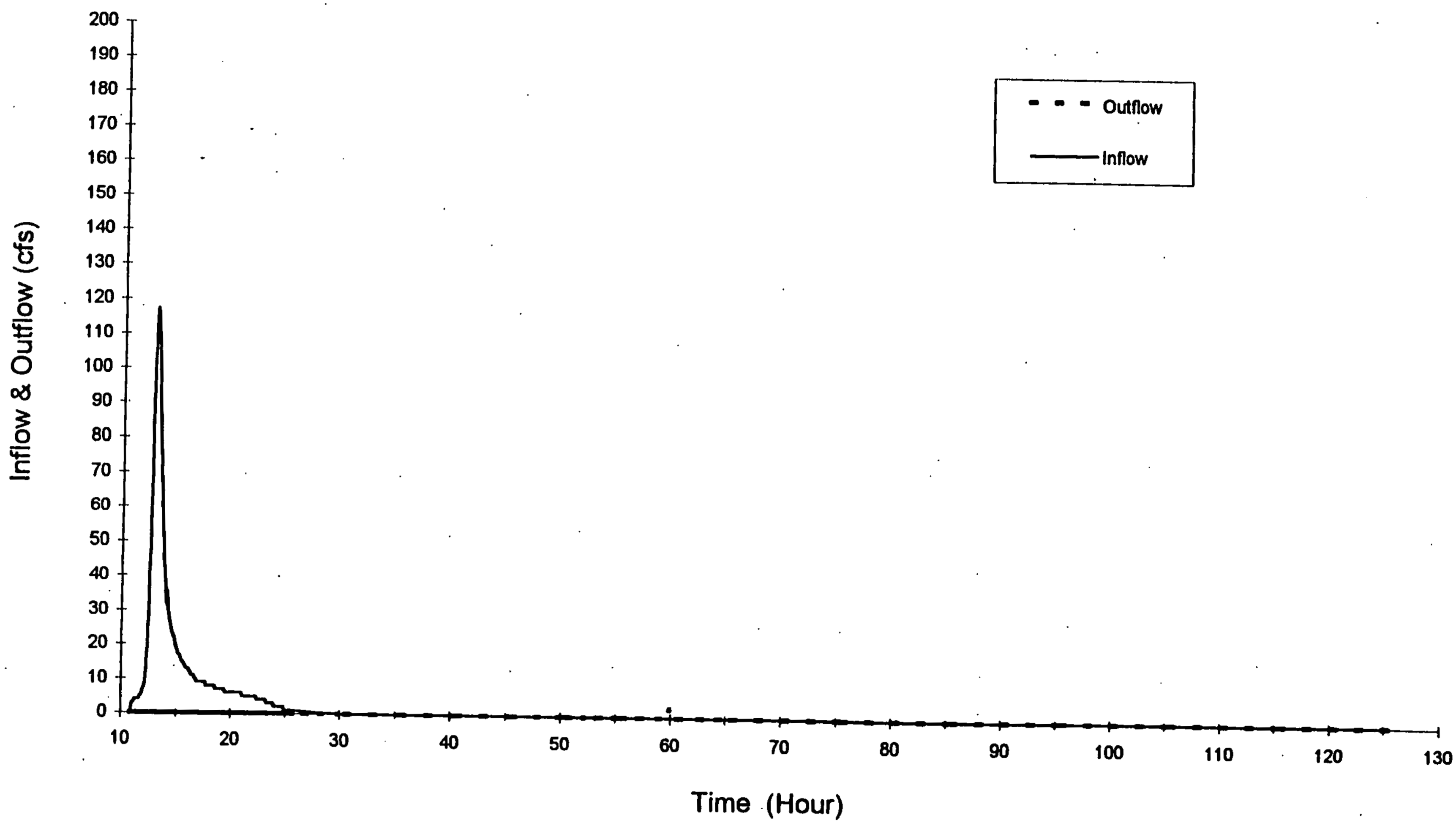

Figure 5-13 Inflow And Outflow Rates of Pond 2 Under Extreme Conditions

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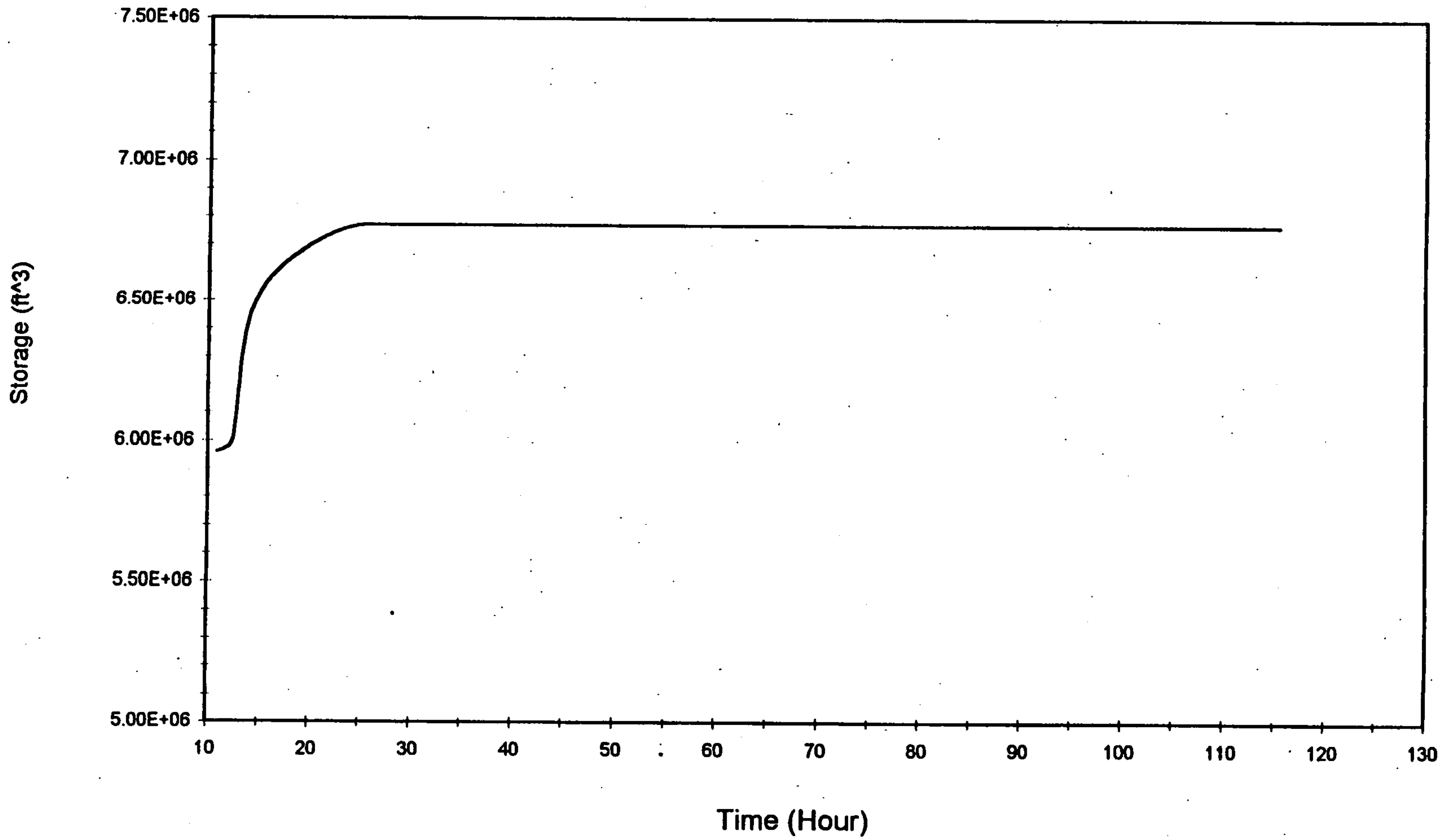

Figure 5-14 Storage Variations of Pond 2 Under Extreme Conditions

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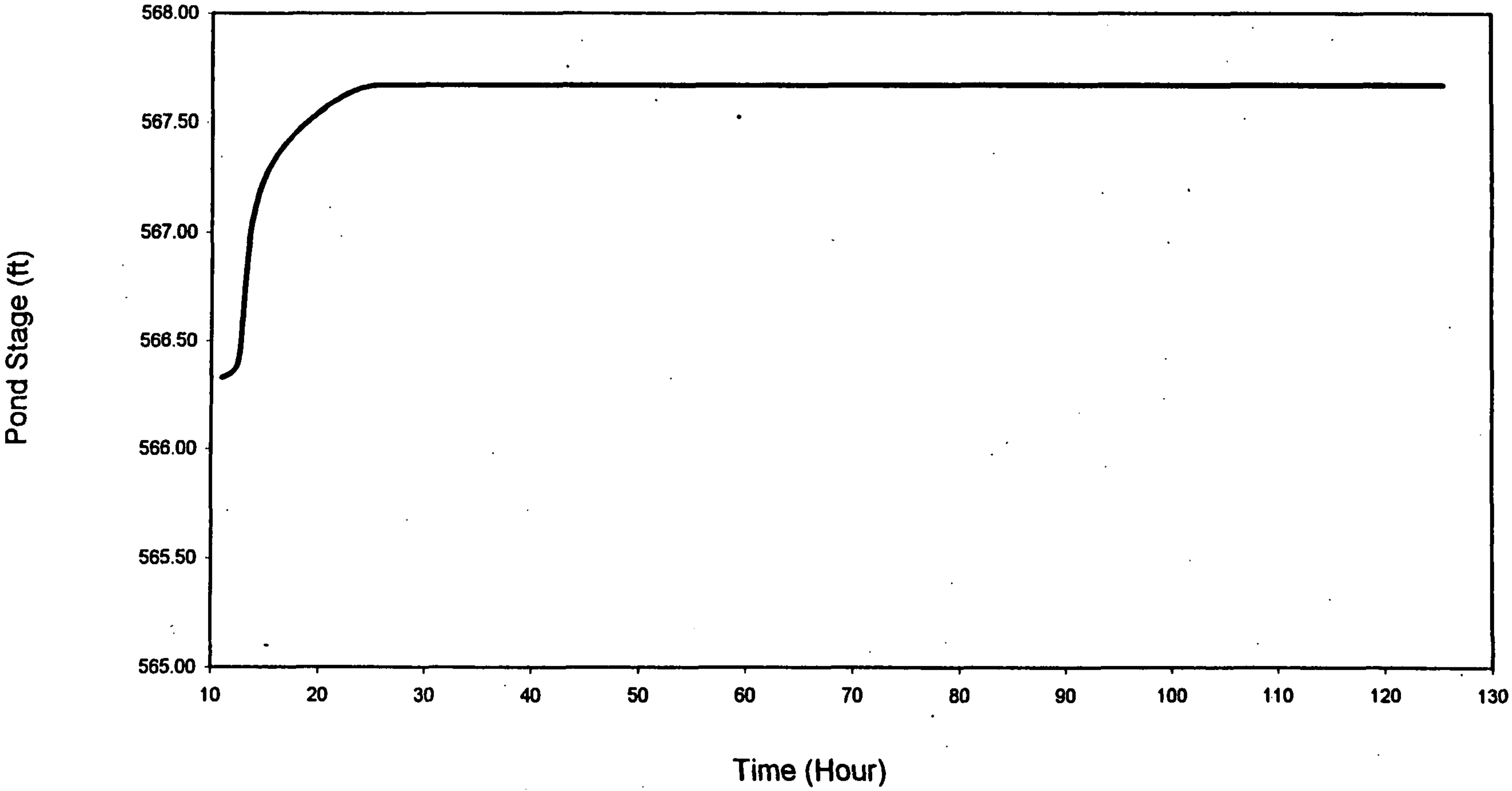

Figure 5-15 Stage Variations of Pond 2 Under Extreme Conditions

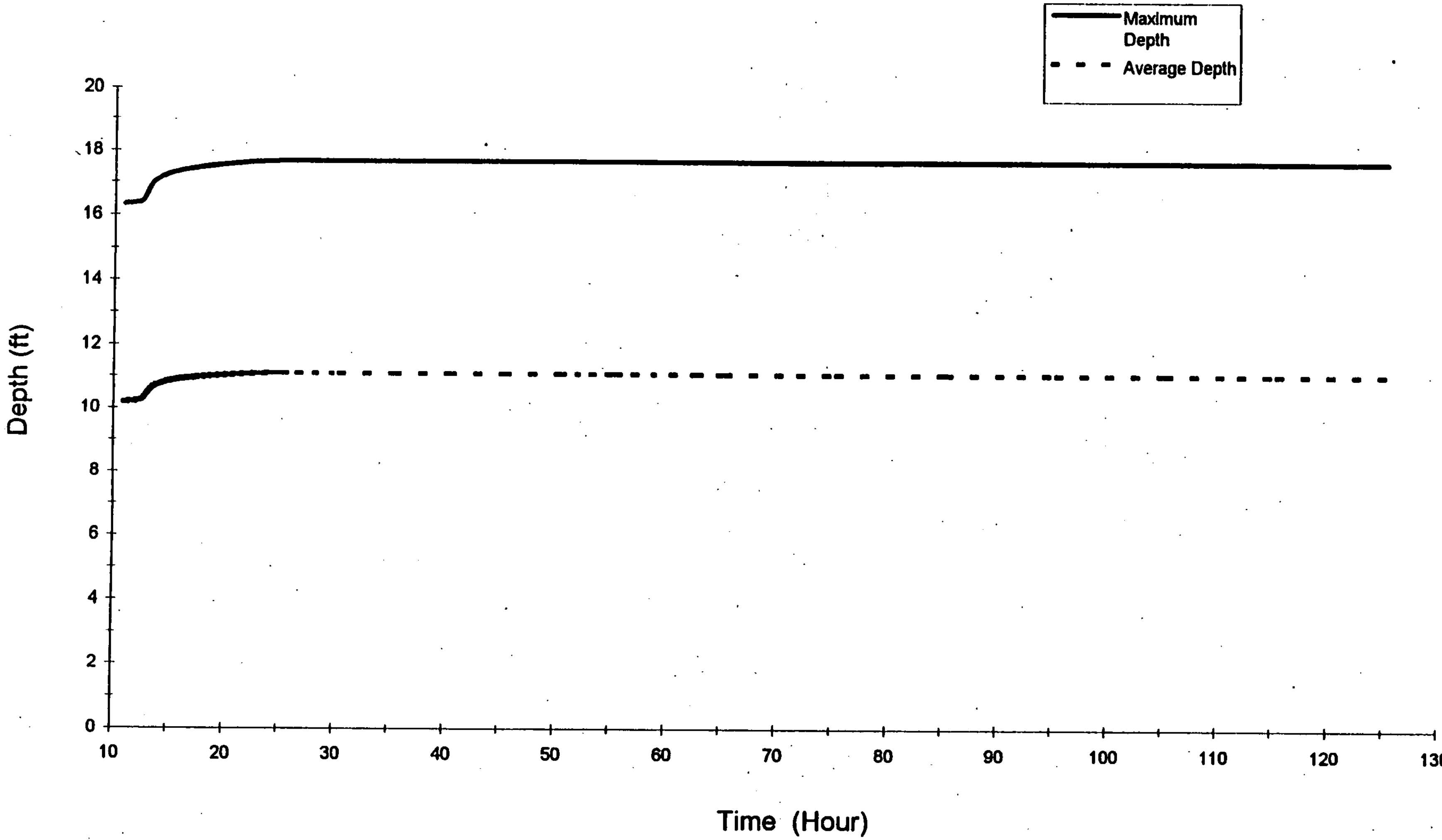

Figure 5-16 Maximum and Average Depth of Pond 2 Under Extreme Conditions

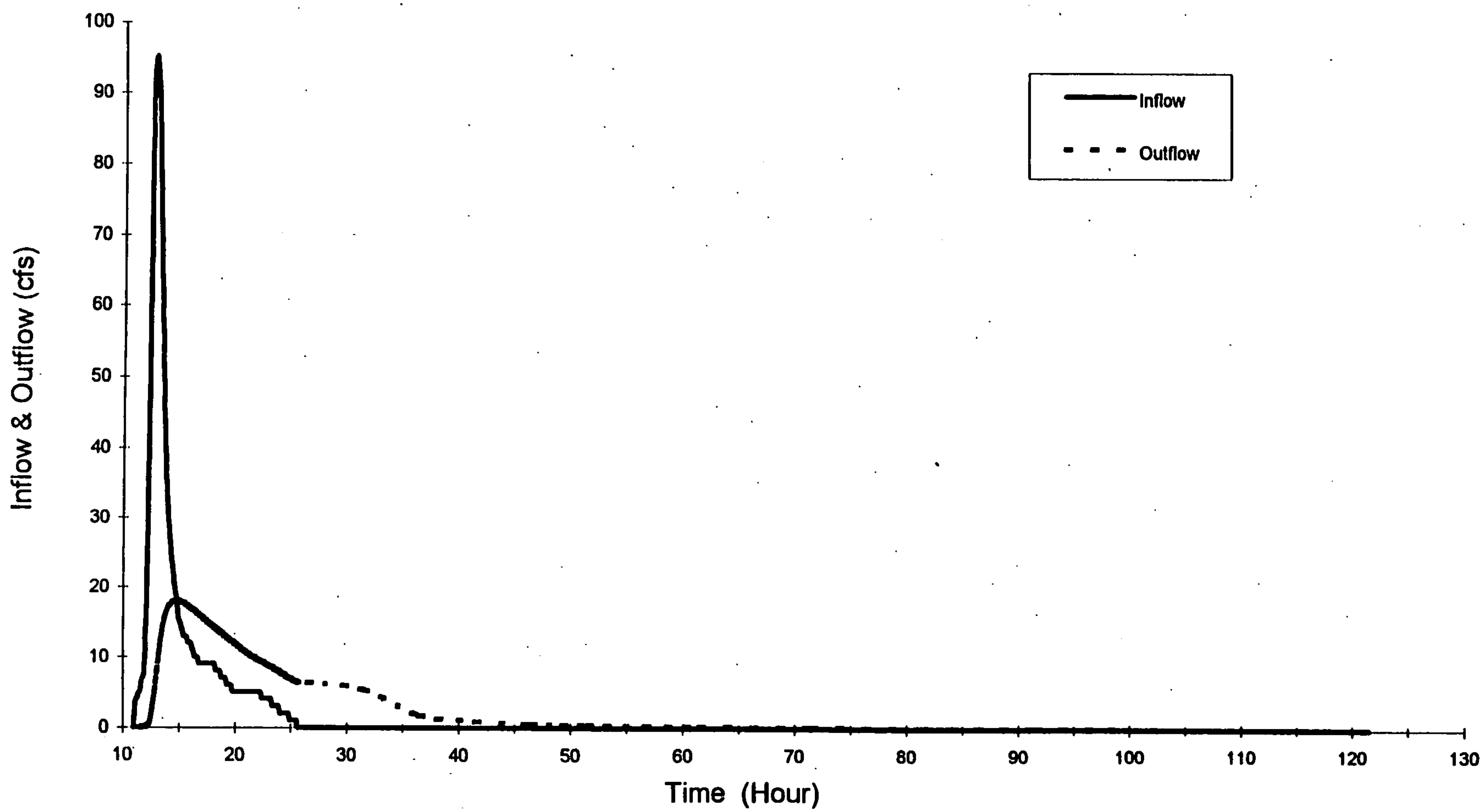

Figure 5-17 Inflow And Outflow Rates of Pond 3 Under Extreme Conditions

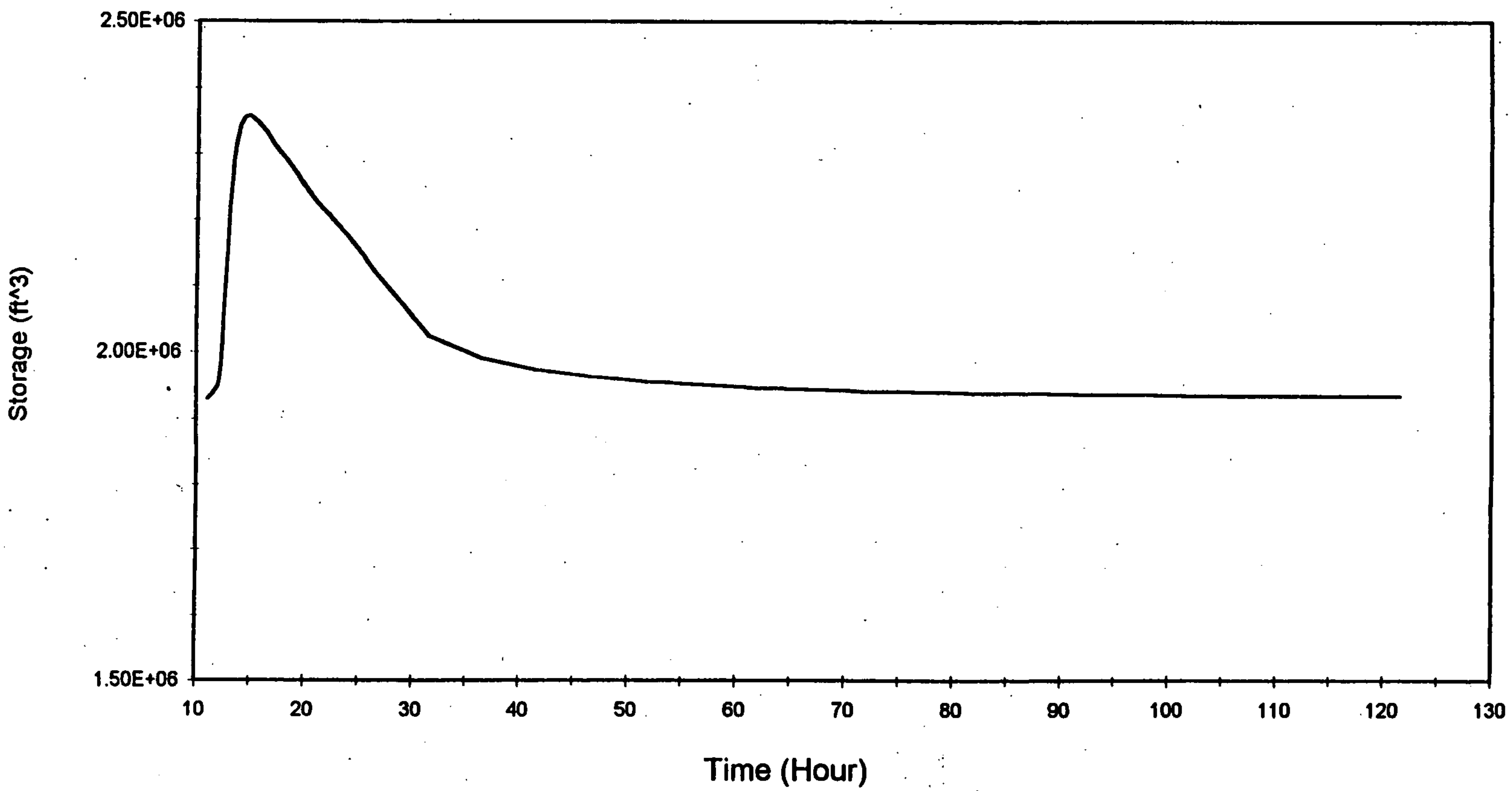

Figure 5-18 Storage Variations of Pond 3 Under Extreme Conditions

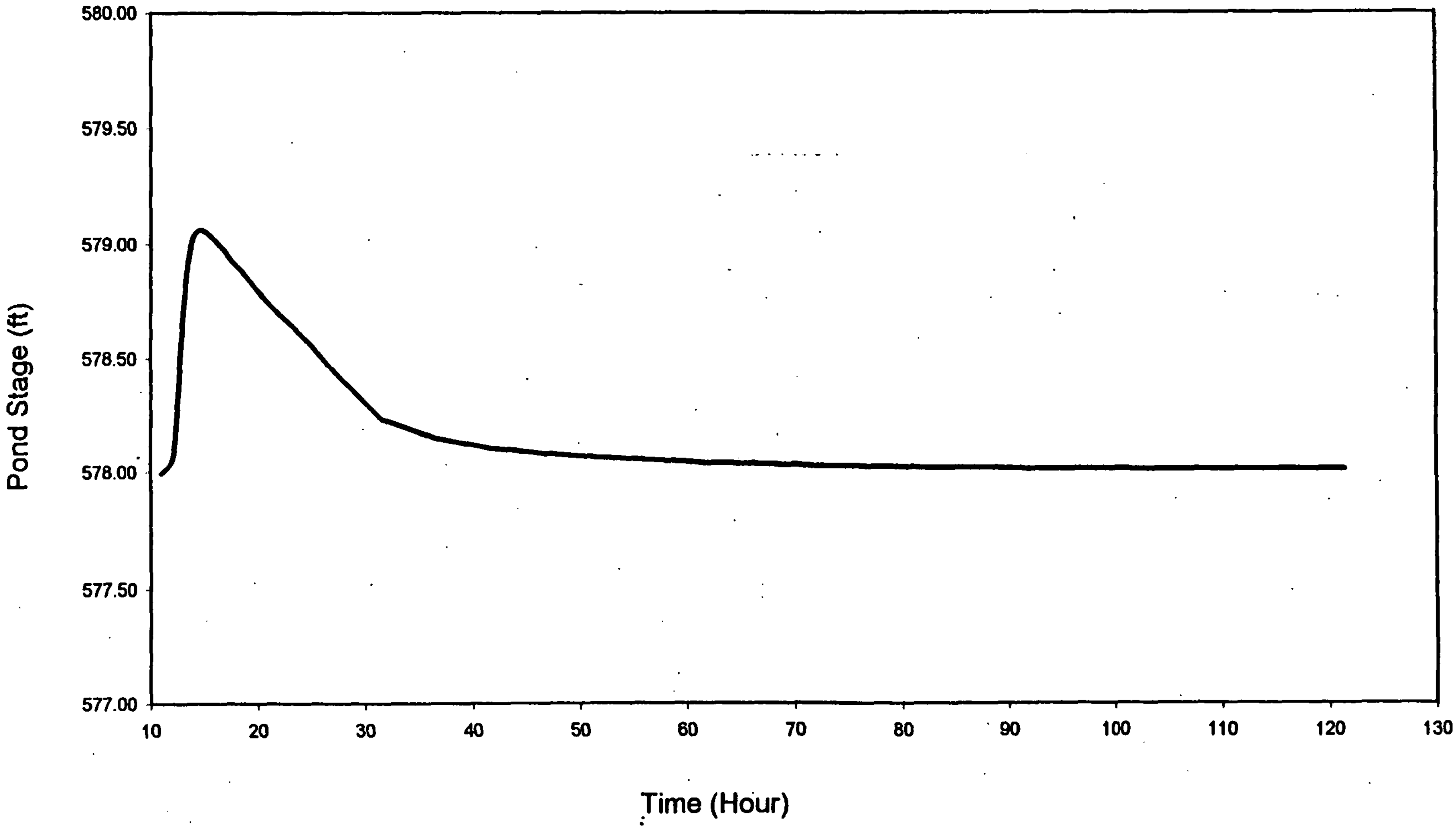

Figure 5-19 Stage Variations of Pond 3 Under Extreme Conditions

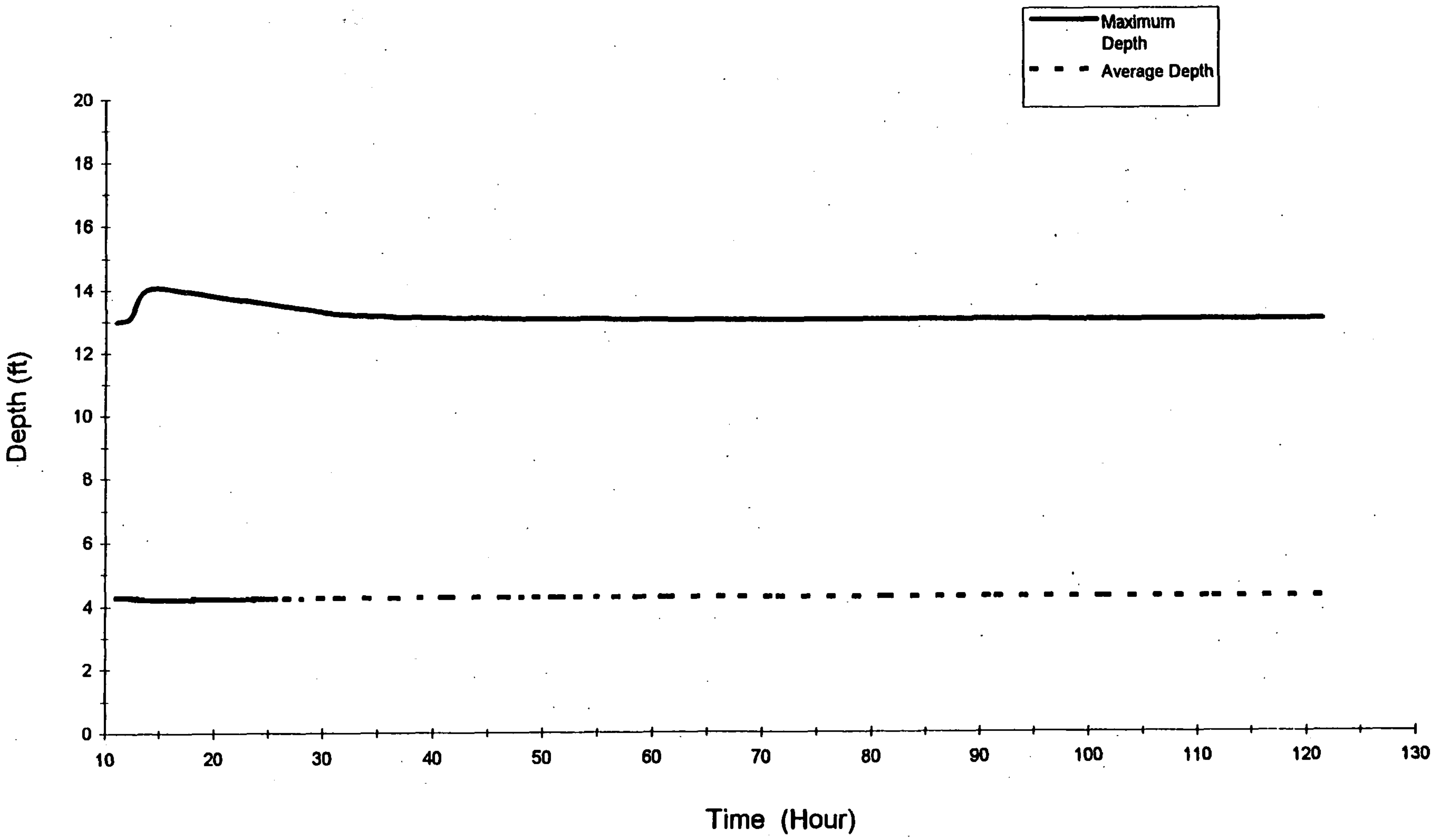

Figure 5-20 Maximum and Average Depth of Pond 3 Under Extreme Conditions

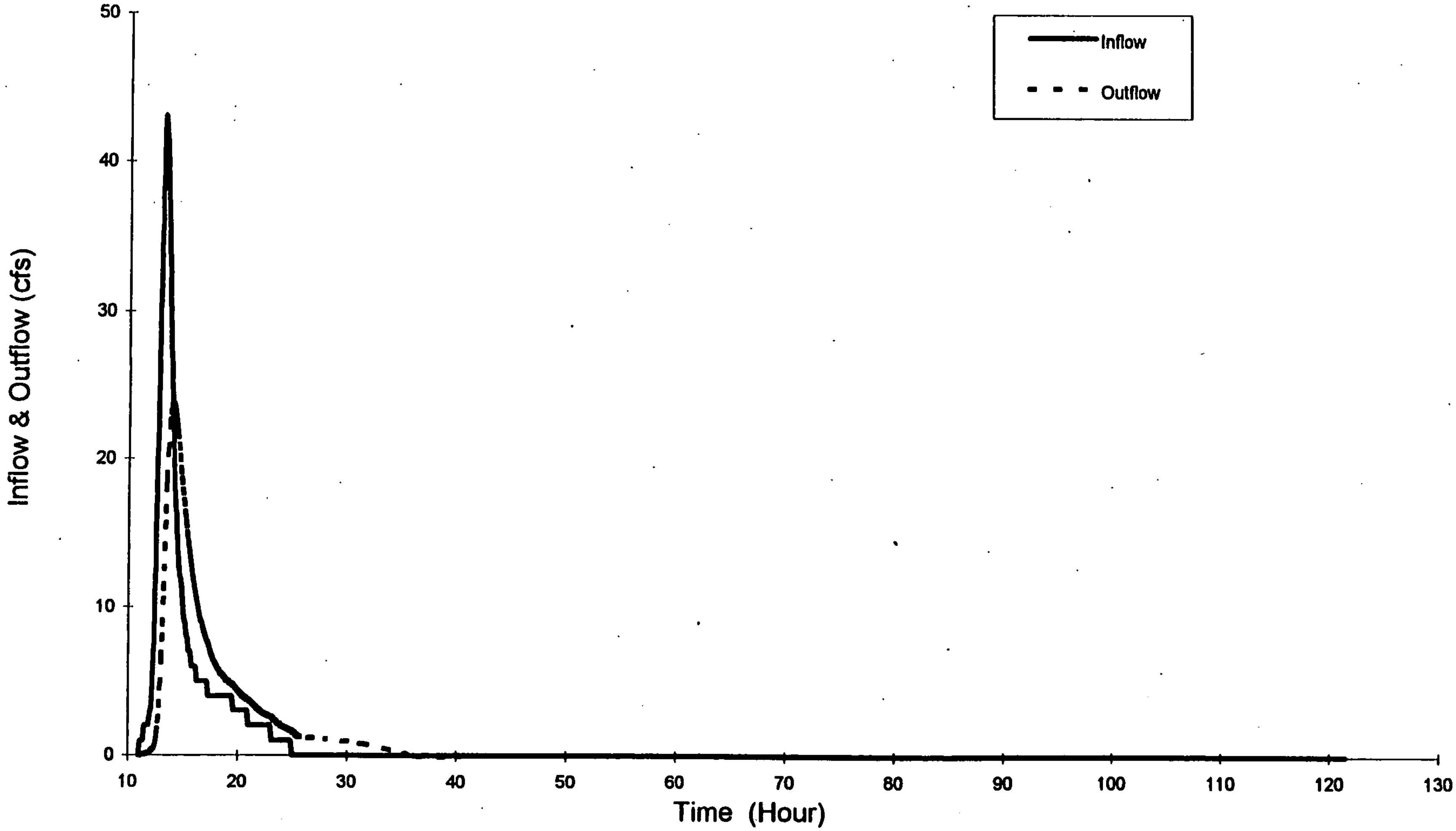

Figure 5-21 Inflow And Outflow Rates of Pond 4 Under Extreme Conditions

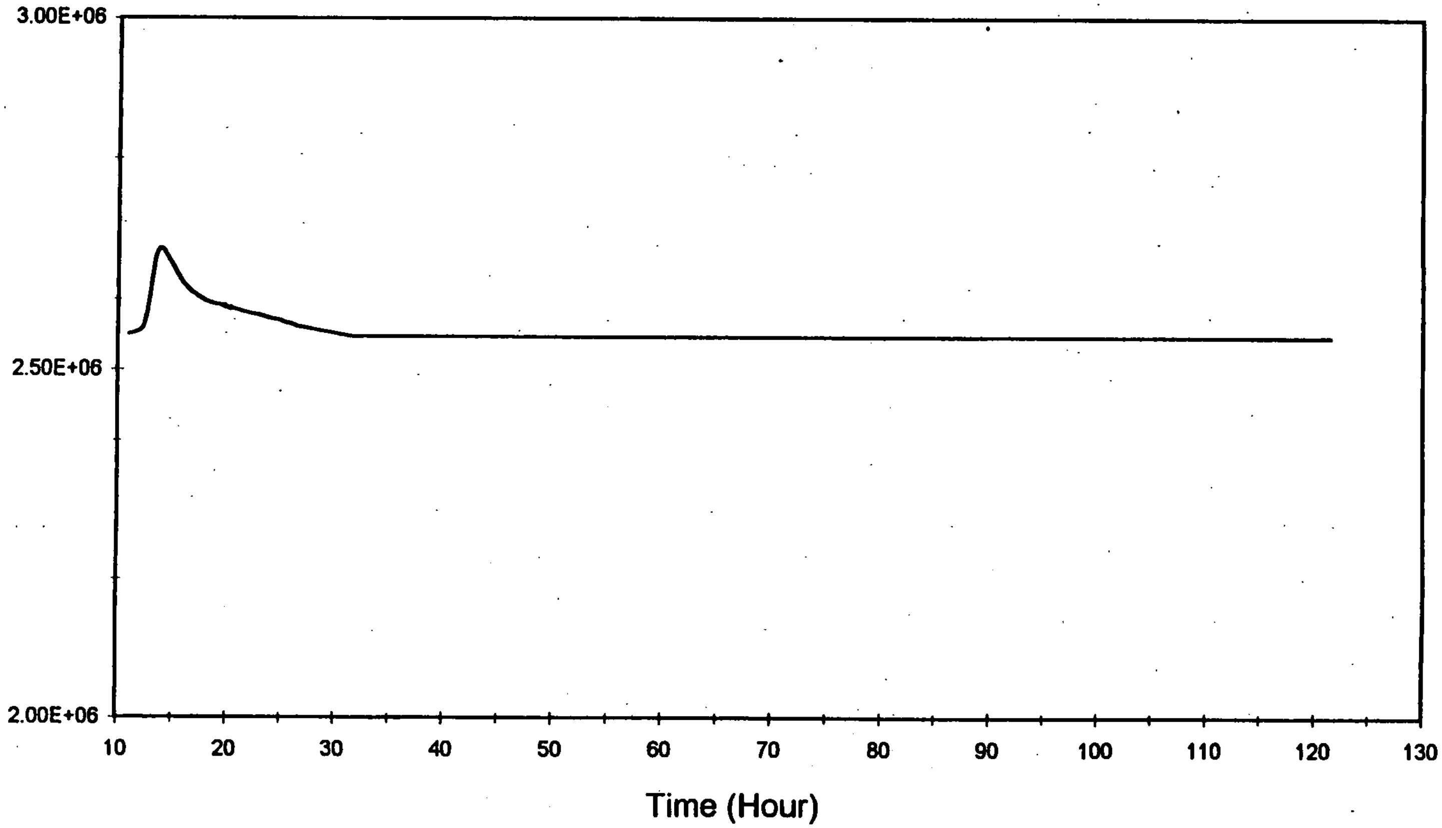

Figure 5-22 Storage Variations of Pond 4 Under Extreme Conditions

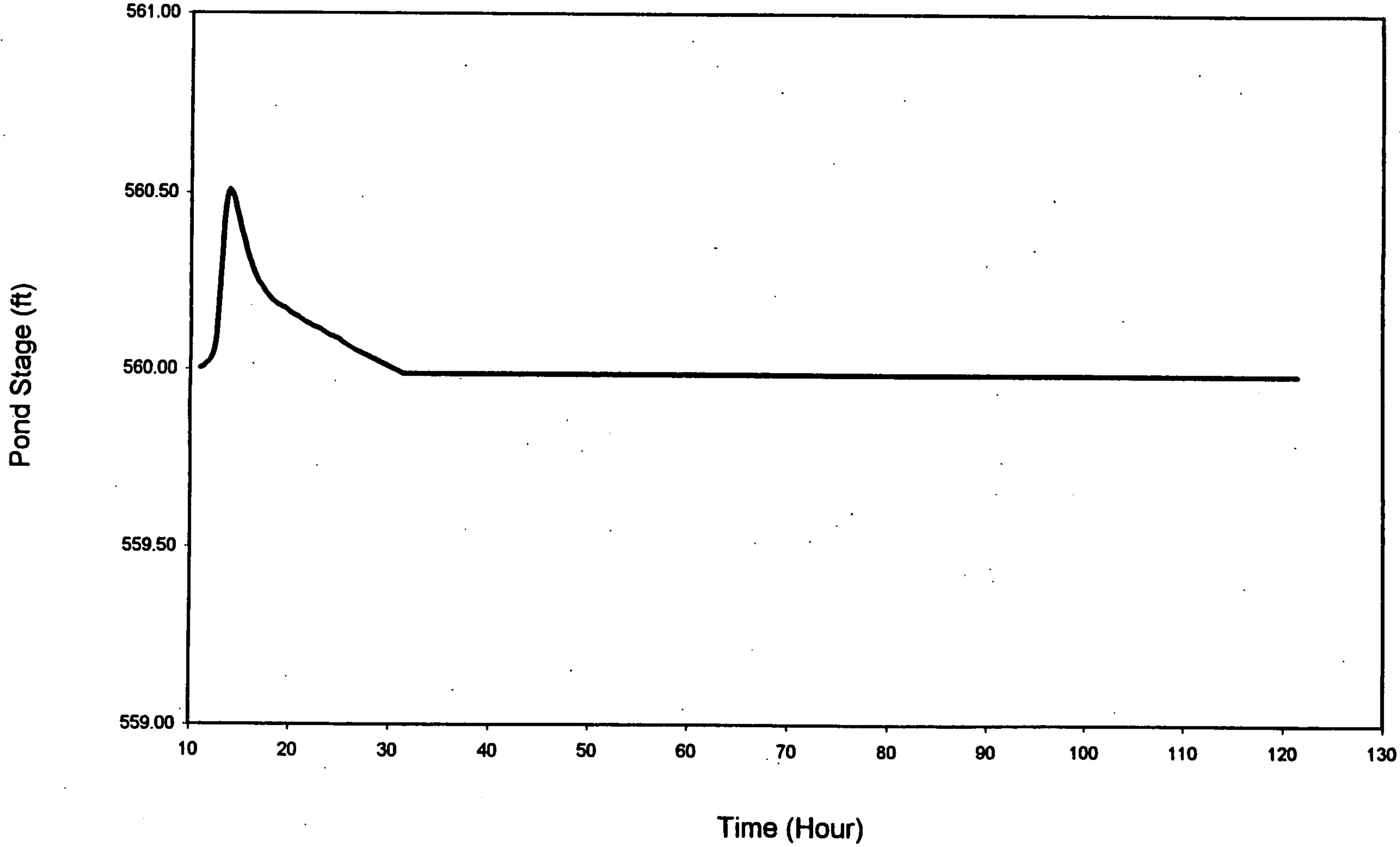

Figure 5-23 Storage Variations of Pond 4 Under Extreme Conditions

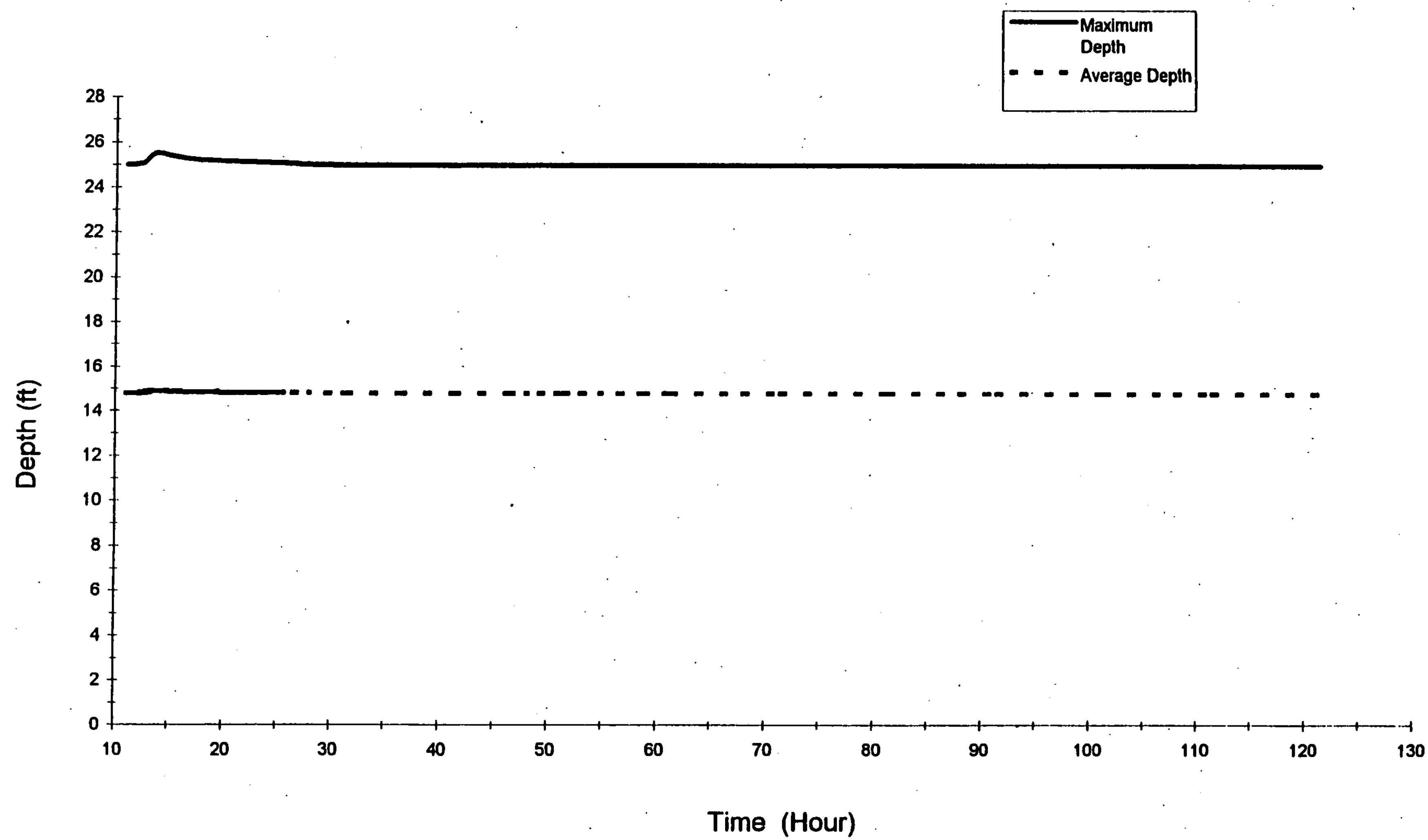

Figure 5-24 Maximum and Average Depth of Pond 4 Under Extreme Conditions

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6.0 SUMMARY AND DISCUSSIONS

The routing modeling results indicated that the maximum pond elevations are constantly below the top edge of the ponds for both normal and extreme conditions evaluated. These results are based on allowing overflow from weirs when the pool levels exceed the outlet bottom elevations. The findings based on the storage routing modeling are briefly summarized for both modeled conditions.

Normal Conditions:

Modeling approaches for normal conditions have incorporated the monthly meteorological data, based on data available from NOAA. Any excessive storage that exceeds the designed outlet bottom elevations are overflowed to the final discharging point.

- Maximum inflow rates and maximum depth normally occur in April.
- Pond 1 has the highest stage (573 feet), if considering Pond 3 as a temporary retention pond.
- Pond 1 has the highest inflow rates (1.1×10^{6} ft^3/month) among the four ponds.
- Pond 4 has the lowest inflow rates (4.2×10^{5} ft^3/month) among the four ponds.
- Pond 2 has the highest storage (6.19×10^{6} ft^3), and Pond 3 has the lowest storage (1.21×10^{6} ft^3).
- Pond 3 has the highest daily overflow rates (2.31×10^{4} ft^3/day).
- Maximum water depths estimated for the four ponds are 18, 16.7, 13, and 25 feet respectively.

Extreme Conditions:

The storm event was modeled by using the TR55 method. The Tabular Hydrograph Method is utilized for modeling multiple subareas that contribute runoff to one common design outfall point in the watershed.

- Time to peak inflow rates are approximately 13 hours.
- Pond 1 has the highest stage (574.1 feet), and Pond 4 has the lowest elevation (560 feet), if considering Pond 3 as a temporary retention pond.
- Pond 1 has the highest inflow rates (129 cfs) among the four ponds.
- Pond 4 has the lowest inflow rates (43 cfs) among the four ponds.
- Pond 2 has the highest storage (6.77×10^{6} ft^3), and Pond 3 has the lowest storage (1.93×10^{6} ft^3).
- Maximum and average water depths reach the highest when the peak inflow rates occur (about 13.0 hours from the beginning of storm inflow).
- Maximum water depths estimated for the four ponds, when the peak inflow appears are approximately 19, 18, 14, and 26 feet respectively

Excess runoff from Pond 1 is allowed to be discharged to the Storm Sewer Outfall Ditch (SSOD). Excess water is also allowed to be drained from Pond 2 to Pond 4 through an open channel. The final outfall point for stormwater runoff routing through Pond 1, Pond 3, and Pond 4 is the SSOD, then to Paddys Run, and eventually to the Great Miami River.

Since soil excavation in the Pond 1 area will reach the unsaturated Great Miami Aquifer, which is generally sandy material with a permeability range 10^{-2} to 10^{-3} cm/sec, the liner material for Pond 1 requires replacement with either a lower permeability clay soil or a synthetic liner. Replacing the sandy soil will facilitate minimum leakage of water through the liner materials.

Based on the modeling results, it is suggested that an underground pipe be connected between Pond 1 and Pond 2. This connection will greatly improve the regulation of water storage between Pond 1 and Pond 2, since Pond 2 has a much larger capacity with approximately seven feet of freeboard under all conditions considered.

REFERENCES

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Haestad, 1989, "Quick TR55 Hydrology for Small Watersheds," Haestad Method Inc., Waterbury, CT.

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U.S. Department of Commerce, 1986, National Oceanic and Atmospheric Administration, "Climate Data Summaries from Hourly Precipitation Data and State Climatic Divisions," August

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9067

APPENDIX A

MONTHLY RUNOFF CALCULATIONS (HELP MODEL)

302
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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\POND2.D4
TEMPERATURE DATA FILE:        C:\HELP3\POND2.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\POND2.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\POND2.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\POND2.D10
OUTPUT DATA FILE:             C:\HELP3\pond2.OUT


TIME:  10:48     DATE:   6/ 3/1997


******************************************************************************

     TITLE:  RUNOFF TO PONDS OF FEMP PER UNIT ACRE (infiltration zone IV)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                    LAYER  1
                                    --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  22
           THICKNESS                    =     120.00  INCHES
           POROSITY                     =       0.4190 VOL/VOL
           FIELD CAPACITY               =       0.3070 VOL/VOL
           WILTING POINT                =       0.1800 VOL/VOL
           INITIAL SOIL WATER CONTENT   =       0.3559 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =   0.189999992000E-04 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	120.00 INCHES
POROSITY	=	0.2000 VOL/VOL
FIELD CAPACITY	=	0.1500 VOL/VOL
WILTING POINT	=	0.1100 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1875 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.699999987000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	74.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.860	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.771	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.620	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	65.212	INCHES
TOTAL INITIAL WATER	=	65.212	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	104
END OF GROWING SEASON (JULIAN DATE)	=	295
AVERAGE ANNUAL WIND SPEED	=	9.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CLEVELAND OHIO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

3.66	2.98	3.67	3.55	3.78	3.59
4.09	2.80	2.59	2.11	3.01	2.86

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.10 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.57	3.10	3.75	3.30	3.52	3.55
	4.31	3.07	2.69	2.17	3.00	2.69
STD. DEVIATIONS	1.17	1.02	1.28	1.25	1.55	1.46
	2.17	1.42	1.26	1.02	1.21	1.09
RUNOFF						
TOTALS	1.242	2.125	0.954	0.053	0.121	0.191
	0.473	0.125	0.078	0.016	0.057	0.187
STD. DEVIATIONS	1.132	1.455	1.056	0.183	0.265	0.341
	0.746	0.315	0.206	0.066	0.214	0.582
EVAPOTRANSPIRATION						
TOTALS	0.913	1.116	2.543	3.052	3.048	3.073
	3.359	2.472	2.196	1.784	1.352	1.003
STD. DEVIATIONS	0.201	0.311	0.324	0.856	1.079	1.165
	1.199	0.996	0.856	0.642	0.297	0.174

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	0.5452	0.4871	0.6067	0.6277	0.6384	0.5958
	0.6359	0.6489	0.6041	0.6430	0.5881	0.5954
STD. DEVIATIONS	0.2126	0.2022	0.1876	0.1621	0.1647	0.1997
	0.1754	0.1556	0.1739	0.1486	0.1718	0.1703

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
IPITATION	38.74	(4.539)	140625.5	100.00
FF	5.621	(2.2746)	20403.37	14.509
OTRANSPIRATION	25.911	(2.7428)	94058.02	66.885
OLATION/LEAKAGE THROUGH YER 2	7.21624	(1.50650)	26194.961	18.62746
GE IN WATER STORAGE	-0.008	(2.9189)	-30.81	-0.022

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	4.24	15391.199
RUNOFF	3.420	12414.7588
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.023811	86.43263
SNOW WATER	5.69	20667.5918

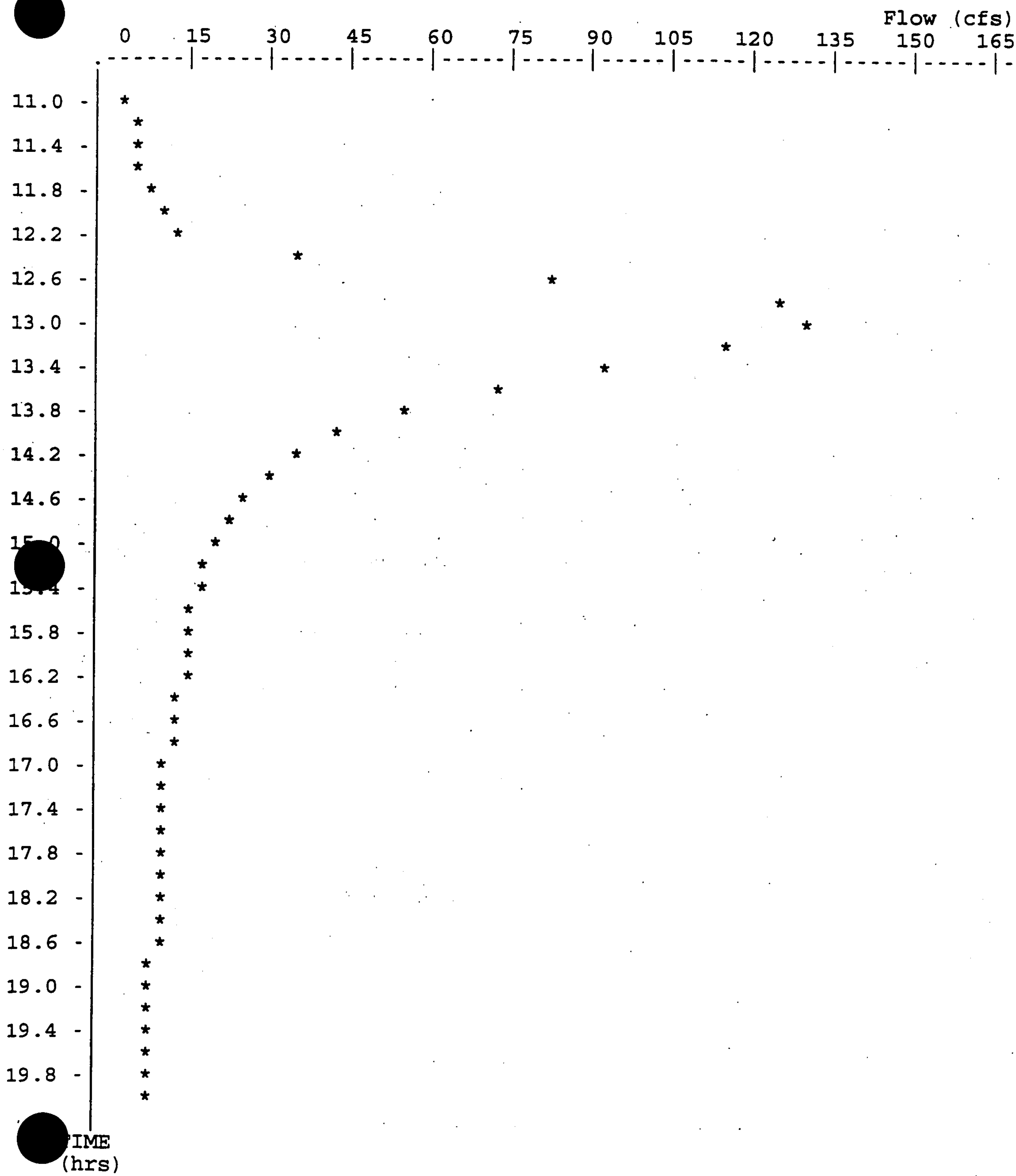
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4190
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1297

****

APPENDIX B

PEAK DISCHARGE AND HYDROGRAPH (TR55 METHOD)

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-05-1997 14:50:23



* File: c:\qtr55\POND1-25.HYD Qmax = 129.0 cfs

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBAREA A	26.40	74.0	0.40	0.50	4.70	2.13	I.15	.15
SUBAREA B	7.10	74.0	0.40	0.40	4.70	2.13	I.15	.15
SUBAREA O	51.30	74.0	0.50	0.50	4.70	2.13	I.15	.15
SUBAREA L	42.50	74.0	0.75	0.75	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 127.30 acres or 0.1989 sq.mi
Peak discharge = 129 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	* Tt (hr)	Rounded Values Tc (hr)	* Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
JBAREA A	0.43	0.43	0.40	0.50	Yes	--
JBAREA B	0.39	0.39	0.40	0.40	Yes	--
JBAREA O	0.55	0.55	0.50	0.50	Yes	--
JBAREA L	0.74	0.74	0.75	0.75	Yes	--

Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBAREA A	36	12.8
SUBAREA B	10	12.7
SUBAREA O	64	12.8
SUBAREA L	44	13.4
Composite Watershed	129	13.0

Quick TR-55 Version: 5.46 S/N: Page 3

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
SUBAREA A	1	1	1	2	2	3	4	7	12
SUBAREA B	0	0	0	1	1	1	1	2	4
SUBAREA O	1	2	3	4	4	5	6	9	15
SUBAREA L	1	1	1	2	2	2	2	3	3
Total (cfs)	3	4	5	9	9	11	13	21	34

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
SUBAREA A	20	28	35	36	30	20	13	9	7
SUBAREA B	7	9	10	10	7	5	3	2	2
SUBAREA O	26	40	54	64	63	48	32	22	16
SUBAREA L	4	6	10	15	29	41	44	39	30
Total (cfs)	57	83	109	125	129	114	92	72	55

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
SUBAREA A	6	5	4	3	3	3	2	2	2
SUBAREA B	1	1	1	1	1	1	1	1	1
SUBAREA O	13	10	8	7	6	6	5	4	4
SUBAREA L	23	15	11	8	6	5	5	4	4
Total (cfs)	43	31	24	19	16	15	13	11	11

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBAREA A	2	2	1	1	0
SUBAREA B	1	0	0	0	0
SUBAREA O	4	3	3	2	0
SUBAREA L	3	3	3	2	0
Total (cfs)	10	8	7	5	0

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	3	14.8	22
11.1	3	14.9	20
11.2	4	15.0	19
11.3	4	15.1	18
11.4	4	15.2	18
11.5	5	15.3	17
11.6	5	15.4	17
11.7	6	15.5	16
11.8	8	15.6	16
11.9	9	15.7	16
12.0	9	15.8	15
12.1	11	15.9	15
12.2	13	16.0	15
12.3	21	16.1	15
12.4	34	16.2	14
12.5	57	16.3	14
12.6	83	16.4	13
12.7	109	16.5	13
12.8	125	16.6	13
12.9	127	16.7	12
13.0	129	16.8	12
13.1	122	16.9	11
13.2	114	17.0	11
13.3	103	17.1	11
13.4	92	17.2	11
13.5	82	17.3	11
13.6	72	17.4	11
13.7	63	17.5	11
13.8	55	17.6	11
13.9	49	17.7	11
14.0	43	17.8	10
14.1	39	17.9	10
14.2	35	18.0	10
14.3	31	18.1	10
14.4	29	18.2	10
14.5	26	18.3	9

14.6	24	18.4	9
14.7	23	18.5	9

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	9	22.4	4
18.7	9	22.5	4
18.8	8	22.6	4
18.9	8	22.7	4
19.0	8	22.8	4
19.1	8	22.9	4
19.2	8	23.0	4
19.3	8	23.1	4
19.4	8	23.2	4
19.5	8	23.3	3
19.6	7	23.4	3
19.7	7	23.5	3
19.8	7	23.6	3
19.9	7	23.7	3
20.0	7	23.8	3
20.1	7	23.9	3
20.2	7	24.0	2
20.3	7	24.1	2
20.4	7	24.2	2
20.5	6	24.3	2
20.6	6	24.4	2
20.7	6	24.5	2
20.8	6	24.6	2
20.9	6	24.7	2
21.0	6	24.8	2
21.1	6	24.9	1
21.2	6	25.0	1
21.3	6	25.1	1
21.4	6	25.2	1
21.5	6	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

Quick TR-55 Ver.5.46 S/N:
Executed: 11:29:57 06-05-1997 c:\qtr55\POND1.TCT

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

POND 1
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBAREA A	Tc	0.43
SUBBASIN B	Tc	0.39
SUBBASIN O	Tc	0.55
SUBAREA L	Tc	0.74

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Quick TR-55 Ver.5.46   S/N:
Executed: 11:29:57   06-05-1997    c:\qtr55\POND1.TCT

                                POND 1
                                 FEMP

                  Tc COMPUTATIONS FOR: SUBAREA A

SHEET FLOW (Applicable to Tc only)
    Segment ID                                          A1
    Surface description                            GRASS
    Manning's roughness coeff., n                      0.3000
    Flow length, L (total < or = 300)          ft      200.0
    Two-yr 24-hr rainfall, P2                  in      2.900
    Land slope, s                           ft/ft      0.1480
                         0.8
         .007 * (n*L)
    T =  -------------                         hrs       0.23          =   0.23
            0.5    0.4
          P2    *   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                       Unpaved
    Flow length, L                              ft      380.0
    Watercourse slope, s                     ft/ft     0.1480

                           0.5
    Avg.V =  Csf *   (s)                      ft/s     6.2071
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                           hrs       0.02          =   0.02

CHANNEL FLOW
    Segment ID                                          A3
    Cross Sectional Flow Area, a            sq.ft      16.00
    Wetted perimeter, Pw                       ft      11.30
    Hydraulic radius, r = a/Pw                 ft      1.416
    Channel slope, s                        ft/ft     0.0050
    Manning's roughness coeff., n                     0.0340

                     2/3     1/2
         1.49   *   r    *   s
    V =  -------------------                  ft/s     3.9074
                    n

    Flow length, L                             ft       2460

    T = L / (3600*V)                           hrs       0.17          =   0.17
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                              TOTAL TIME (hrs)         0.43
```

318
~~319~~

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Quick TR-55 Ver.5.46   S/N:
Executed: 11:29:57    06-05-1997    c:\qtr55\POND1.TCT

                                     POND 1
                                      FEMP


                       Tc COMPUTATIONS FOR: SUBBASIN B

 SHEET FLOW (Applicable to Tc only)
     Segment ID
     Surface description                        GRASS
     Manning's roughness coeff., n                    0.3000
     Flow length, L (total < or = 300)          ft    300.0
     Two-yr 24-hr rainfall, P2                  in    2.900
     Land slope, s                           ft/ft    0.1480
                               0.8
               .007 * (n*L)
     T =    -------------                      hrs      0.32           =   0.32
               0.5     0.4
             P2    *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID
     Surface (paved or unpaved)?                     Unpaved
     Flow length, L                             ft    150.0
     Watercourse slope, s                    ft/ft    0.1480

                                 0.5
     Avg.V =   Csf *   (s)                    ft/s    6.2071
     where:    Unpaved Csf = 16.1345
               Paved   Csf = 20.3282

     T = L / (3600*V)                          hrs      0.01           =   0.01

 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a            sq.ft    16.00
     Wetted perimeter, Pw                       ft    11.30
     Hydraulic radius, r = a/Pw                 ft    1.416
     Channel slope, s                        ft/ft    0.0050
     Manning's roughness coeff., n                    0.0340

                              2/3     1/2
             1.49   *   r    *   s
     V =   --------------------               ft/s    3.9074
                        n

     Flow length, L                             ft      810

     T = L / (3600*V)                          hrs      0.06           =   0.06

 ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                                  TOTAL TIME (hrs)        0.39
```

319

320

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Quick TR-55 Ver.5.46   S/N:
Executed: 11:29:57   06-05-1997     c:\qtr55\POND1.TCT

                                POND 1
                                 FEMP


                     Tc COMPUTATIONS FOR: SUBBASIN O

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                        GRASS
    Manning's roughness coeff., n                      0.3000
    Flow length, L (total < or = 300)          ft      300.0
    Two-yr 24-hr rainfall, P2                  in      2.900
    Land slope, s                              ft/ft   0.2300
                          0.8
          .007 * (n*L)
    T =   -------------                        hrs       0.27          =   0.27
            0.5      0.4
          P2     *   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                       Unpaved
    Flow length, L                             ft      1650.0
    Watercourse slope, s                       ft/ft   0.0100

                               0.5
    Avg.V =  Csf *   (s)                       ft/s    1.6135
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                           hrs       0.28          =   0.28

CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a               sq.ft     0.00
    Wetted perimeter, Pw                       ft        0.00
    Hydraulic radius, r = a/Pw                 ft       0.000
    Channel slope, s                           ft/ft   0.0000
    Manning's roughness coeff., n                      0.0000

                      2/3     1/2
           1.49   *  r    *  s
    V =   -------------------                  ft/s    0.0000
                     n

    Flow length, L                             ft           0

    T = L / (3600*V)                           hrs       0.00          =   0.00
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                                  TOTAL TIME (hrs)         0.55
```

320
321

```
Quick TR-55 Ver.5.46   S/N:
Executed: 11:29:57   06-05-1997     c:\qtr55\POND1.TCT

                                   POND 1
                                    FEMP


                    Tc COMPUTATIONS FOR: SUBAREA L

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                   GRASS
    Manning's roughness coeff., n               0.3000
    Flow length, L (total < or = 300)    ft     150.0
    Two-yr 24-hr rainfall, P2            in     2.900
    Land slope, s                      ft/ft   0.0100
                         0.8
       .007 * (n*L)
    T = -------------                    hrs      0.55              =  0.55
          0.5    0.4
        P2    *   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                Unpaved
    Flow length, L                       ft     950.0
    Watercourse slope, s               ft/ft   0.0070

                           0.5
    Avg.V =  Csf *   (s)                ft/s   1.3499
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                     hrs      0.20              =  0.20


CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a       sq.ft      0.00
    Wetted perimeter, Pw                 ft       0.00
    Hydraulic radius, r = a/Pw           ft      0.000
    Channel slope, s                   ft/ft    0.0000
    Manning's roughness coeff., n               0.0000

                        2/3    1/2
        1.49   *   r    *   s
    V = -------------------             ft/s    0.0000
                   n

    Flow length, L                       ft          0

    T = L / (3600*V)                     hrs      0.00              =  0.00
    ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                        TOTAL TIME (hrs)            0.74
```

321
~~322~~

Quick TR-55 Ver.5.46 S/N:
Executed: 14:18:47 06-05-1997

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

TRAVEL TIME COMPUTATION
POND1 - NORTHEAST OF FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBAREA A	Tt	0.00
SUBAREA B	Tt	0.00
SUBAREA O	Tt	0.19
SUBAREA L	Tt	0.00

Quick TR-55 Version: 5.46 S/N:

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHARGE
POND 1 -AT NORTHEAST OF FEMP

CALCULATED .GPD
DISK FILE: c:\qtr55\POND1 .GPD

Drainage Area	(acres)	127.3 --->	0.1989 sq.mi.
Runoff Curve Number	(CN)	74	
Time of Concentration,Tc	(hrs)	.75	
Rainfall Distribution	(Type)	II	
Pond and Swamp Areas	(%)	1 --->	1.3 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	5	25	100
Rainfall, P, 24-hr (in)	3.7	4.7	5.6
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.190	0.150	0.125
Unit Discharge, * qu (csm/in)	390	405	414
Runoff, Q (in)	1.38	2.13	2.85
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	93	149	204

Summary of Computations for qu

Ia/p	#1	0.100	0.100	0.100
C0	#1	2.553	2.553	2.553
C1	#1	-0.615	-0.615	-0.615
C2	#1	-0.164	-0.164	-0.164
qu (csm)	#1	424.152	424.152	424.152
Ia/p	#2	0.300	0.300	0.300
C0	#2	2.465	2.465	2.465
C1	#2	-0.623	-0.623	-0.623
C2	#2	-0.117	-0.117	-0.117
qu (csm)	#2	347.763	347.763	347.763
* qu (csm)		390	405	414

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$
$$qp\ (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond\ \&\ Swamp\ Adj.)$$

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND1 - NORTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND1 .DET

Drainage Area	(acres)	127.3	0.1989 sq.mi.
Rainfall Distribution	(Type)	II	

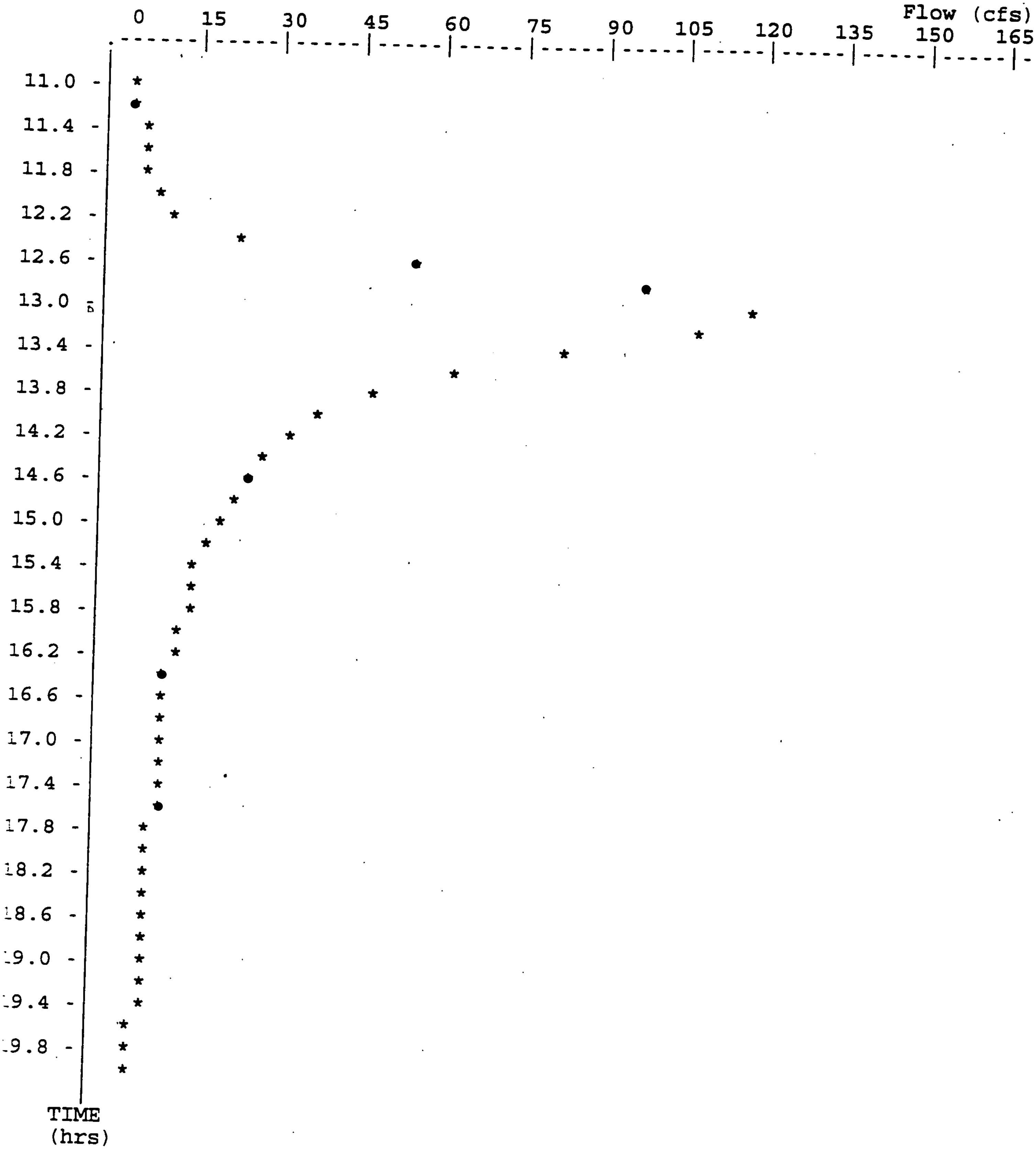
	Storm #1	Storm #2	Storm #3
Frequency (years)	5	25	100
Peak Inflow, qi (cfs)	93	149	204
Inflow Runoff, Q (in)	1.38	2.13	2.85
Peak Outflow, qo (cfs)	0	0	0
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.682	0.682
Inflow Volume, Vr (ac-ft)	14.6	22.6	30.2
STORAGE VOLUME, Vs (ac-ft)	10.0	15.4	20.6

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.682	0.682

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-05-1997 15:47:36



* File: c:\qtr55\POND2-25.HYD Qmax = 117.0 cfs

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBBASIN N	51.80	74.0	0.20	0.75	4.70	2.13	I.15	.15
SUBBASIN M	57.40	74.0	1.50	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 109.20 acres or 0.1706 sq.mi
Peak discharge = 117 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
SUBBASIN N	0.29	0.65	0.20	0.75	Yes	--
SUBBASIN M	1.44	0.00	1.50	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN N	71	13.0
SUBBASIN M	50	13.2
Composite Watershed	117	13.0

Quick TR-55 Version: 5.46 S/N: Page 3
Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
SUBBASIN N	1	2	2	3	3	4	4	6	9
SUBBASIN M	1	2	2	3	4	4	6	9	13
Total (cfs)	2	4	4	6	7	8	10	15	22

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
SUBBASIN N	17	29	45	60	71	57	38	25	17
SUBBASIN M	19	25	32	38	46	50	44	37	30
Total (cfs)	36	54	77	98	117	107	82	62	47

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
SUBBASIN N	13	10	9	7	6	6	5	4	4
SUBBASIN M	25	19	15	12	9	7	6	5	5
Total (cfs)	38	29	24	19	15	13	11	9	9

·barea ription	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN N	4	3	3	2	0
SUBBASIN M	4	4	3	3	0

Total (cfs)	8	7	6	5	0

```
Quick TR-55 Ver.5.46   S/N:
Executed: 16:17:01   06-05-1997   c:\qtr55\POND3.TCT

                         TIME OF CONCENTRATION
                       POND 3 - SOUTHEAST FEMP
                                 FEMP

                   Tc COMPUTATIONS FOR: SUBBASIN F

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                       GRASS
    Manning's roughness coeff., n                   0.3000
    Flow length, L (total < or = 300)     ft       300.0
    Two-yr 24-hr rainfall, P2             in       2.900
    Land slope, s                         ft/ft    0.0150
                          0.8
         .007 * (n*L)
    T =  --------------                   hrs       0.81          =  0.81
            0.5     0.4
          P2    *   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                   Unpaved
    Flow length, L                        ft       510.0
    Watercourse slope, s                  ft/ft    0.0200

                            0.5
    Avg.V =   Csf  *   (s)                ft/s     2.2818
    where:    Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

    T = L / (3600*V)                      hrs       0.06          =  0.06

CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a          sq.ft    32.00
    Wetted perimeter, Pw                  ft       17.90
    Hydraulic radius, r = a/Pw            ft       1.788
    Channel slope, s                      ft/ft    0.0050
    Manning's roughness coeff., n                  0.0340

                      2/3     1/2
         1.49   *   r    *   s
    V =  --------------------             ft/s     4.5645
                    n

    Flow length, L                        ft        2070

    T = L / (3600*V)                      hrs       0.13          =  0.13

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                                                TOTAL TIME (hrs)     1.00
```

Quick TR-55 Ver.5.46 S/N:
Executed: 16:17:01 06-05-1997 c:\qtr55\POND3.TCT

TIME OF CONCENTRATION
POND 3 - SOUTHEAST FEMP
FEMP

Tc COMPUTATIONS FOR: SUBBASIN H

SHEET FLOW (Applicable to Tc only)

Segment ID				
Surface description	GRASS			
Manning's roughness coeff., n		0.3000		
Flow length, L (total < or = 300)	ft	300.0		
Two-yr 24-hr rainfall, P2	in	2.900		
Land slope, s	ft/ft	0.0100		
$T = \dfrac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.95	=	0.95

SHALLOW CONCENTRATED FLOW

Segment ID				
Surface (paved or unpaved)?		Unpaved		
Flow length, L	ft	1400.0		
Watercourse slope, s	ft/ft	0.0100		
$Avg.V = Csf * (s)^{0.5}$	ft/s	1.6135		
where: Unpaved Csf = 16.1345				
Paved Csf = 20.3282				
T = L / (3600*V)	hrs	0.24	=	0.24

CHANNEL FLOW

Segment ID				
Cross Sectional Flow Area, a	sq.ft	0.00		
Wetted perimeter, Pw	ft	0.00		
Hydraulic radius, r = a/Pw	ft	0.000		
Channel slope, s	ft/ft	0.0000		
Manning's roughness coeff., n		0.0000		
$V = \dfrac{1.49 * r^{2/3} * s^{1/2}}{n}$	ft/s	0.0000		
Flow length, L	ft	0		
T = L / (3600*V)	hrs	0.00	=	0.00

::

TOTAL TIME (hrs) 1.19

Quick TR-55 Version: 5.46 S/N:

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

POND 2 - NORTHWEST FEMP
FEMP
25 YEAR RETURN PERIOD, 24 HOUR DURATION STORM

CALCULATED
DISK FILE: c:\qtr55\POND2 .GPD

Drainage Area	(acres)	109.2	--->	0.1706 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	.95		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	1.1 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	352	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	111	0	0

Summary of Computations for qu

		Storm #1	Storm #2	Storm #3
Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	368.851	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	301.391	0.000	0.000
* qu (csm)		352	0	0

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$
qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND 2 - NORTHWEST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND2 .DET

Drainage Area	(acres)	109.2	0.1706 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	117		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	19.4	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	13.2	0.0	0.0

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

* $Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$

Quick TR-55 Version: 5.46 S/N: Page 1
Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBBASIN C	36.50	74.0	0.50	0.10	4.70	2.13	I.15	.15
SUBBASIN E	7.20	74.0	1.00	0.30	4.70	2.13	I.15	.15
SUBBASIN F	23.00	74.0	1.00	0.10	4.70	2.13	I.15	.15
SUBBASIN H	37.30	74.0	1.25	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I Subarea where user specified interpolation between Ia/p tables.

Total area = 104.00 acres or 0.1625 sq.mi
Peak discharge = 95 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
SUBBASIN C	0.59	0.07	0.50	0.10	Yes	--
SUBBASIN E	1.02	0.24	1.00	0.30	Yes	--
SUBBASIN F	1.00	0.07	1.00	0.10	Yes	--
SUBBASIN H	1.19	0.00	1.25	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN C	57	12.5
SUBBASIN E	7	13.0
SUBBASIN F	25	13.0
SUBBASIN H	37	13.0
Composite Watershed	95	12.8

Quick TR-55 Version: 5.46 S/N: Page 3

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
JBBASIN C	1	2	3	5	7	13	24	40	52
JBBASIN E	0	0	0	0	0	1	1	1	1
JBBASIN F	1	1	1	1	2	2	2	4	6
JBBASIN H	1	1	2	2	3	4	5	8	13
ot cfs)	3	4	6	8	12	20	32	53	72

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
JBBASIN C	57	52	43	34	21	14	11	9	7
JBBASIN E	2	3	4	6	7	7	6	5	4
JBBASIN F	10	14	18	22	25	22	17	13	10
JBBASIN H	18	24	29	33	37	32	26	20	16
otal (cfs)	87	93	94	95	90	75	60	47	37

Quick TR-55 Version: 5.46 S/N:

Page 4
Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
SUBBASIN C	7	6	5	4	4	4	3	3	3
SUBBASIN E	3	2	2	1	1	1	1	1	1
SUBBASIN F	8	6	5	4	3	3	2	2	2
SUBBASIN H	13	10	8	6	5	4	4	3	3
Total (cfs)	31	24	20	15	13	12	10	9	9

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN C	3	2	2	2	0
SUBBASIN E	1	0	0	0	0
SUBBASIN F	2	2	1	1	0
SUBBASIN H	3	3	2	2	0
Total (cfs)	9	7	5	5	0

ck TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	3	14.8	18
11.1	3	14.9	16
11.2	4	15.0	15
11.3	4	15.1	15
11.4	5	15.2	14
11.5	5	15.3	14
11.6	6	15.4	13
11.7	7	15.5	13
11.8	7	15.6	13
11.9	8	15.7	13
12.0	12	15.8	12
12.1	20	15.9	12
12.2	32	16.0	12
12.3	53	16.1	12
12.4	72	16.2	11
12.5	87	16.3	11
12.6	93	16.4	10
12.7	94	16.5	10
12.8	95	16.6	10
12.9	92	16.7	10
13.0	90	16.8	9
13.1	82	16.9	9
13.2	75	17.0	9
13.3	67	17.1	9
13.4	60	17.2	9
13.5	54	17.3	9
13.6	47	17.4	9
13.7	42	17.5	9
13.8	37	17.6	9
13.9	34	17.7	9
14.0	31	17.8	9
14.1	29	17.9	9
14.2	26	18.0	9
14.3	24	18.1	9
14.4	23	18.2	9
14.5	21	18.3	8

14.6	20	18.4	8
14.7	19	18.5	8

'ck TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	2	14.8	22
11.1	3	14.9	20
11.2	3	15.0	19
11.3	4	15.1	18
11.4	4	15.2	17
11.5	4	15.3	17
11.6	4	15.4	16
11.7	5	15.5	15
11.8	5	15.6	15
11.9	6	15.7	14
12.0	7	15.8	14
12.1	8	15.9	13
12.2	10	16.0	13
12.3	15	16.1	13
12.4	22	16.2	12
12.5	36	16.3	12
12.6	54	16.4	11
12.7	77	16.5	11
12.8	98	16.6	11
12.9	108	16.7	10
13.0	117	16.8	10
13.1	112	16.9	9
13.2	107	17.0	9
13.3	94	17.1	9
13.4	82	17.2	9
13.5	72	17.3	9
13.6	62	17.4	9
13.7	54	17.5	9
13.8	47	17.6	9
13.9	42	17.7	9
14.0	38	17.8	8
14.1	35	17.9	8
14.2	32	18.0	8
14.3	29	18.1	8
14.4	27	18.2	8
14.5	26	18.3	8

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	7	22.4	4
18.7	7	22.5	4
18.8	7	22.6	4
18.9	7	22.7	4
19.0	7	22.8	4
19.1	7	22.9	4
19.2	7	23.0	4
19.3	7	23.1	4
19.4	7	23.2	4
19.5	6	23.3	3
19.6	6	23.4	3
19.7	6	23.5	3
19.8	6	23.6	3
19.9	6	23.7	3
20.0	6	23.8	3
20.1	6	23.9	3
20.2	6	24.0	2
20.3	6	24.1	2
20.4	6	24.2	2
20.5	6	24.3	2
20.6	6	24.4	2
20.7	6	24.5	2
20.8	6	24.6	2
20.9	6	24.7	2
21.0	6	24.8	2
21.1	5	24.9	1
21.2	5	25.0	1
21.3	5	25.1	1
21.4	5	25.2	1
21.5	5	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

Quick TR-55 Ver.5.46 S/N:
Executed: 16:44:51 06-05-1997

SCS RUNOFF CN NUMBER
POND 3 - SOUTHEAST FEMP
FEMP

RUNOFF CURVE NUMBER SUMMARY

Subarea Description	Area (acres)	CN (weighted)
SUBBASIN C	36.50	74
SUBBASIN E	7.20	74
SUBBASIN F	23.00	74
SUBBASIN H	37.30	74

```
Quick TR-55 Ver.5.46   S/N:
Executed: 16:17:01   06-05-1997    c:\qtr55\POND3.TCT

                         TIME OF CONCENTRATION
                        POND 3 - SOUTHEAST FEMP
                                 FEMP

                   Tc COMPUTATIONS FOR: SUBBASIN C

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                      GRASS
    Manning's roughness coeff., n                 0.3000
    Flow length, L (total < or = 300)      ft     300.0
    Two-yr 24-hr rainfall, P2              in     2.900
    Land slope, s                        ft/ft    0.1480
                         0.8
        .007 * (n*L)
    T = --------------                    hrs      0.32              =  0.32
             0.5    0.4
           P2    *   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                  Unpaved
    Flow length, L                         ft     190.0
    Watercourse slope, s                 ft/ft    0.1480

                            0.5
    Avg.V =  Csf •   (s)                  ft/s    6.2071
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                      hrs      0.01              =  0.01

CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a         sq.ft    40.50
    Wetted perimeter, Pw                   ft     27.70
    Hydraulic radius, r = a/Pw             ft     1.462
    Channel slope, s                     ft/ft    0.0050
    Manning's roughness coeff., n                 0.0340

                        2/3    1/2
       1.49   *   r    *   s
    V = --------------------              ft/s    3.9919
                  n

    Flow length, L                         ft      3720

    T = L / (3600*V)                      hrs      0.26              =  0.26

::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                    TOTAL TIME (hrs)         0.59
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Quick TR-55 Ver.5.46    S/N:
Executed: 16:17:01    06-05-1997    c:\qtr55\POND3.TCT

                         TIME OF CONCENTRATION
                       POND 3 - SOUTHEAST FEMP
                                 FEMP

                  Tc COMPUTATIONS FOR: SUBBASIN E

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                    GRASS
    Manning's roughness coeff., n                 0.3000
    Flow length, L (total < or = 300)      ft     300.0
    Two-yr 24-hr rainfall, P2              in     2.900
    Land slope, s                          ft/ft  0.0100
                          0.8
          .007 * (n*L)
    T =   --------------                   hrs    0.95          =  0.95
             0.5    0.4
           P2   *  s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                   Unpaved
    Flow length, L                         ft     60.0
    Watercourse slope, s                   ft/ft  0.0100

                       0.5
    Avg.V =  Csf *  (s)                    ft/s   1.6135
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                       hrs    0.01          =  0.01

CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a           sq.ft  32.00
    Wetted perimeter, Pw                   ft     17.90
    Hydraulic radius, r = a/Pw             ft     1.788
    Channel slope, s                       ft/ft  0.0050
    Manning's roughness coeff., n                 0.0340

                     2/3    1/2
         1.49  *  r    *  s
    V =  -------------------               ft/s   4.5645
                   n

    Flow length, L                         ft     980

    T = L / (3600*V)                       hrs    0.06          =  0.06

:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                         TOTAL TIME (hrs)        1.02
```

14.6	24	18.4	8
14.7	23	18.5	8

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	8	22.4	4
18.7	8	22.5	4
18.8	7	22.6	4
18.9	7	22.7	4
19.0	7	22.8	4
19.1	7	22.9	4
19.2	7	23.0	4
19.3	6	23.1	4
19.4	6	23.2	4
19.5	6	23.3	3
19.6	6	23.4	3
19.7	6	23.5	3
19.8	5	23.6	3
19.9	5	23.7	3
20.0	5	23.8	3
20.1	5	23.9	3
20.2	5	24.0	2
20.3	5	24.1	2
20.4	5	24.2	2
20.5	5	24.3	2
20.6	5	24.4	2
20.7	5	24.5	2
20.8	5	24.6	2
20.9	5	24.7	2
21.0	5	24.8	2
21.1	5	24.9	1
21.2	5	25.0	1
21.3	5	25.1	1
21.4	5	25.2	1
21.5	5	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

Quick TR-55 Ver.5.46 S/N:
Executed: 16:17:01 06-05-1997 c:\qtr55\POND3.TCT

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

TIME OF CONCENTRATION
POND 3 - SOUTHEAST FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN C	Tc	0.59
SUBBASIN E	Tc	1.02
SUBBASIN F	Tc	1.00
SUBBASIN H	Tc	1.19

Quick TR-55 Ver.5.46 S/N:
Executed: 16:40:59 06-05-1997

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

TRAVEL TIME COMPUTATION
POND 3 - SOUTHEAST FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN C	Tt	0.07
SUBBASIN E	Tt	0.24
SUBBASIN F	Tt	0.07
SUBBASIN H	Tt	0.00

Quick TR-55 Ver.5.46 S/N:
Executed: 16:40:59 06-05-1997

TRAVEL TIME COMPUTATION
POND 3 - SOUTHEAST FEMP
FEMP

Tc or Tt DATA

::

Subarea: SUBBASIN C

DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME hours
CHANNEL THROUGH A CULVERT TO	1200	4.54	4.4	=	0.07
		TOTAL Tt --->	4.4	=	0.07

::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN E

DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME hours
CHANNEL THROUGH SUBAREA F	2700	4.50	10.0	=	0.[illegible]
CHANNEL THROUGH CULVERT PIPE	1200	4.50	4.4	=	0.07
		TOTAL Tt --->	14.4	=	0.24

::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN F

DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME hours
CHANNEL THROUGH CULVERT PIPE	1200	4.50	4.4	=	0.07
		TOTAL Tt --->	4.4	=	0.07

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Quick TR-55 Ver.5.46 S/N:
ecuted: 16:40:59 06-05-1997

Subarea: SUBBASIN H DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes	hours

	minutes		hours
TOTAL Tt --->	0.0	=	0.00

Quick TR-55 Version: 5.46 S/N:

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHARGE
POND 3 - SOUTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND3 .GPD

Drainage Area	(acres)	104	--->	0.1625 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	.66		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	1.0 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	436	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	131	0	0

Summary of Computations for qu

Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	455.922	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	374.861	0.000	0.000
* qu (csm)		436	0	0

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND 3 - SOUTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND3 .DET

Drainage Area	(acres)	104	0.1625 sq.mi.
Rainfall Distribution	(Type)	II	

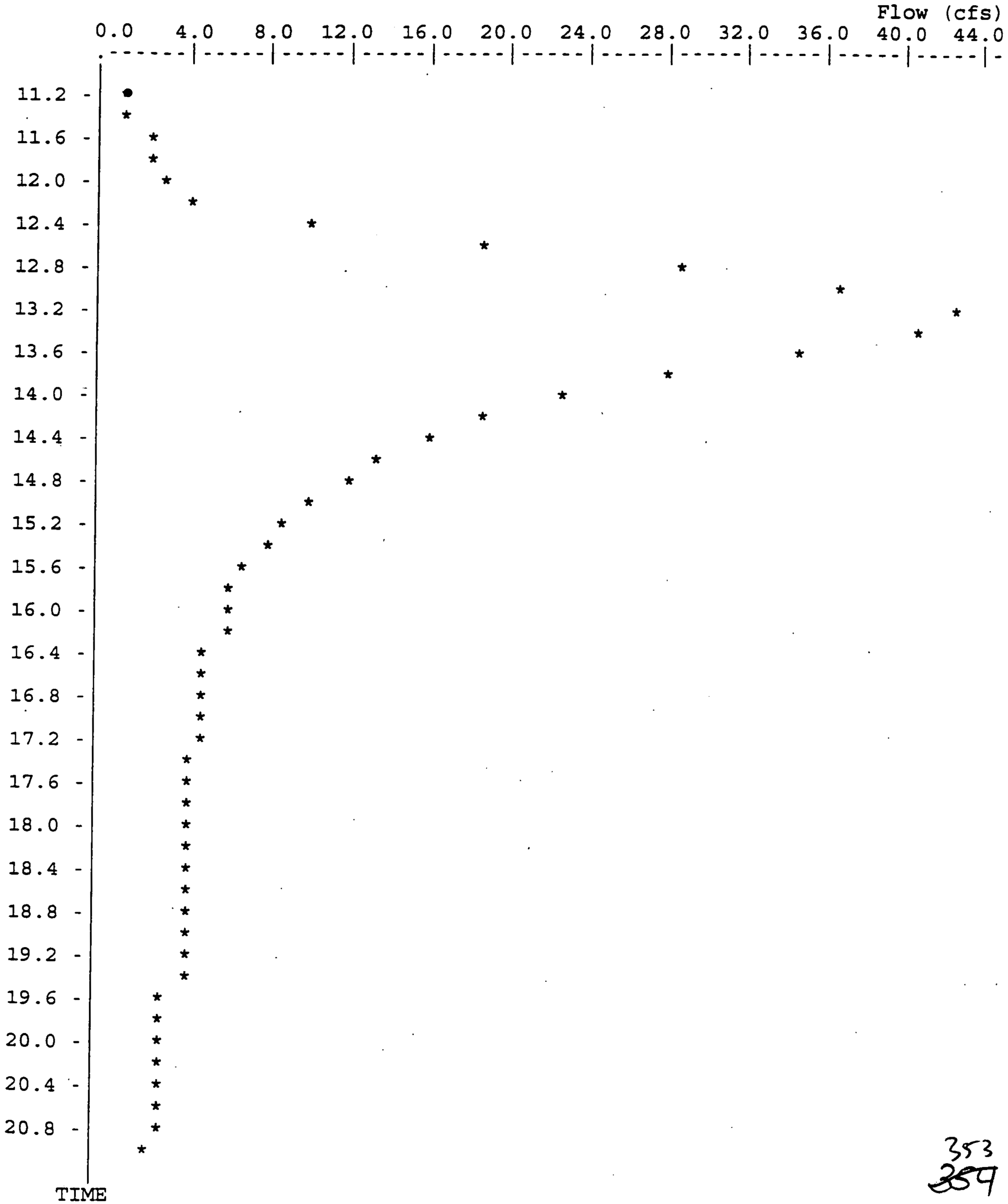
	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	~~130~~ 131		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	18.5	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	12.6	0.0	0.0

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

* $Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-09-1997 16:59:27



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Quick TR-55 Version: 5.46 S/N:

Page 1
Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBBASIN K	8.70	74.0	0.50	1.00	4.70	2.13	I.15	.15
SUBBASIN J	40.60	74.0	1.50	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 49.30 acres or 0.07703 sq.mi
Peak discharge = 43 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	* Tt (hr)	Rounded Values Tc (hr)	* Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
SUBBASIN K	0.62	0.86	0.50	1.00	Yes	--
SUBBASIN J	1.58	0.00	1.50	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN K	10	13.4
SUBBASIN J	35	13.2
Composite Watershed	43	13.2

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
SUBBASIN K	0	0	0	0	0	0	0	1	1
SUBBASIN J	1	1	2	2	3	3	4	6	9
Total (cfs)	1	1	2	2	3	3	4	7	10

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
SUBBASIN K	1	1	1	2	5	8	10	9	7
SUBBASIN J	13	18	22	27	32	35	31	26	21
Total (cfs)	14	19	23	29	37	43	41	35	28

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
SUBBASIN K	5	3	2	2	1	1	1	1	1
SUBBASIN J	18	14	11	8	6	5	4	4	3
Total (cfs)	23	17	13	10	7	6	5	5	4

ˋubarea ːcription	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN K	1	1	1	0	0
SUBBASIN J	3	3	2	2	0

Total (cfs)	4	4	3	2	0

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	1	14.8	12
11.1	1	14.9	11
11.2	1	15.0	10
11.3	1	15.1	9
11.4	1	15.2	9
11.5	2	15.3	8
11.6	2	15.4	8
11.7	2	15.5	7
11.8	2	15.6	7
11.9	2	15.7	7
12.0	3	15.8	6
12.1	3	15.9	6
12.2	4	16.0	6
12.3	7	16.1	6
12.4	10	16.2	6
12.5	14	16.3	5
12.6	19	16.4	5
12.7	23	16.5	5
12.8	29	16.6	5
12.9	33	16.7	5
13.0	37	16.8	5
13.1	40	16.9	5
13.2	43	17.0	5
13.3	42	17.1	5
13.4	41	17.2	5
13.5	38	17.3	4
13.6	35	17.4	4
13.7	32	17.5	4
13.8	28	17.6	4
13.9	26	17.7	4
14.0	23	17.8	4
14.1	21	17.9	4
14.2	19	18.0	4
14.3	17	18.1	4
14.4	16	18.2	4
14.5	14	18.3	4

14.6	13	18.4	4
14.7	12	18.5	4

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	4	22.4	2
18.7	4	22.5	2
18.8	4	22.6	2
18.9	4	22.7	2
19.0	4	22.8	2
19.1	4	22.9	2
19.2	4	23.0	2
19.3	4	23.1	1
19.4	4	23.2	1
19.5	4	23.3	1
19.6	3	23.4	1
19.7	3	23.5	1
19.8	3	23.6	1
19.9	3	23.7	1
20.0	3	23.8	1
20.1	3	23.9	1
20.2	3	24.0	1
20.3	3	24.1	1
20.4	3	24.2	1
20.5	3	24.3	1
20.6	3	24.4	1
20.7	3	24.5	1
20.8	3	24.6	1
20.9	3	24.7	1
21.0	2	24.8	1
21.1	2	24.9	1
21.2	2	25.0	0
21.3	2	25.1	0
21.4	2	25.2	0
21.5	2	25.3	0
21.6	2	25.4	0
21.7	2	25.5	0
21.8	2	25.6	0
21.9	2	25.7	0
22.0	2	25.8	0
22.1	2	25.9	0
22.2	2		
22.3	2		

Quick TR-55 Ver.5.46 S/N:
Executed: 16:32:57 06-09-1997

SCS RUNOFF CURVE NUMBER
POND 4 - RETENTION POND
FEMP

RUNOFF CURVE NUMBER SUMMARY

Subarea Description	Area (acres)	CN (weighted)
K	8.70	74
SUBBASIN J	40.60	74

Quick TR-55 Ver.5.46 S/N:
Executed: 16:32:57 06-09-1997

SCS RUNOFF CURVE NUMBER
POND 4 - RETENTION POND
FEMP

RUNOFF CURVE NUMBER DATA

Composite Area: K

SURFACE DESCRIPTION	AREA (acres)	CN	
GRASS	8.70	74	
COMPOSITE AREA --->	8.70	74.0	(74)

Composite Area: SUBBASIN J

SURFACE DESCRIPTION	AREA (acres)	CN	
GRASS	40.60	74	
COMPOSITE AREA --->	40.60	74.0	(74)

Quick TR-55 Ver.5.46 S/N:
Executed: 16:23:41 06-09-1997 c:\qtr55\POND4.TCT

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

POND 4 - RETENTION POND
TIME OF CONCENTRATION
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN K	Tc	0.62
SUBBASIN J	Tc	1.58

```
Quick TR-55 Ver.5.46    S/N:
Executed: 16:23:41    06-09-1997    c:\qtr55\POND4.TCT

                         POND 4 - RETENTION POND
                           TIME OF CONCENTRATION
                                   FEMP

                      Tc COMPUTATIONS FOR: SUBBASIN K

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                        GRASS
    Manning's roughness coeff., n                    0.3000
    Flow length, L (total < or = 300)        ft      580.0
    Two-yr 24-hr rainfall, P2                in      2.900
    Land slope, s                          ft/ft     0.1480
                         0.8
         .007 * (n*L)
    T =  --------------                      hrs       0.55              =  0.55
            0.5    0.4
          P2    *   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?
    Flow length, L                           ft        0.0
    Watercourse slope, s                   ft/ft     0.0000

                           0.5
    Avg.V =  Csf  *   (s)                    ft/s    0.0000
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                         hrs       0.00              =  0.00

CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a           sq.ft     16.00
    Wetted perimeter, Pw                     ft      11.30
    Hydraulic radius, r = a/Pw               ft      1.416
    Channel slope, s                       ft/ft     0.0050
    Manning's roughness coeff., n                    0.0340

                      2/3    1/2
         1.49  *   r    *   s
    V =  --------------------                ft/s    3.9074
                   n

    Flow length, L                           ft       1020

    T = L / (3600*V)                         hrs       0.07              =  0.07

:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                                   TOTAL TIME (hrs)     0.62
```

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Quick TR-55 Ver.5.46   S/N:
Executed: 16:23:41   06-09-1997    c:\qtr55\POND4.TCT

                         POND 4 - RETENTION POND
                          TIME OF CONCENTRATION
                                  FEMP

                    Tc COMPUTATIONS FOR: SUBBASIN J

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                        GRASS
    Manning's roughness coeff., n                    0.3000
    Flow length, L (total < or = 300)      ft       300.0
    Two-yr 24-hr rainfall, P2              in        2.900
    Land slope, s                          ft/ft     0.0050
                          0.8
        .007 * (n*L)
    T = -------------                      hrs        1.25            =  1.25
           0.5    0.4
         P2    *  s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                    Unpaved
    Flow length, L                         ft       600.0
    Watercourse slope, s                   ft/ft     0.0010

                           0.5
    Avg.V =  Csf *  (s)                    ft/s     0.5102
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                       hrs        0.33            =  0.33

CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a           sq.ft      0.00
    Wetted perimeter, Pw                   ft         0.00
    Hydraulic radius, r = a/Pw             ft        0.000
    Channel slope, s                       ft/ft     0.0000
    Manning's roughness coeff., n                    0.0000

                     2/3    1/2
        1.49  *  r    *  s
    V = -------------------                ft/s     0.0000
                 n

    Flow length, L                         ft            0

    T = L / (3600*V)                       hrs        0.00            =  0.00
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                             TOTAL TIME (hrs)        1.58
```

~~366~~
365

Quick TR-55 Ver.5.46 S/N:
Executed: 16:30:29 06-09-1997

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

POND 4 - RETENTION POND
TRAVEL TIME
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
K	Tt	0.86
SUBBASIN J	Tt	0.00

Quick TR-55 Ver.5.46   S/N:
Executed: 16:30:29   06-09-1997

POND 4 - RETENTION POND
TRAVEL TIME
FEMP

Tc or Tt DATA

::

Subarea: K DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes	 hours
CHANNEL THROUGH SUBAREA J	1580	0.51	51.6 =	0.86
			minutes	hours
		TOTAL Tt --->	51.6 =	0.86

::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN J DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes	 hours
OUTFALL AT RETENTION POND	0	0.00	0.0 =	0.[illegible]
			minutes	hours
		TOTAL Tt --->	0.0 =	0.00

::::::::::::::::::::::::::::::::::

Quick TR-55 Version: 5.46 S/N:

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHATGE
POND 4 -RETEMTION POND
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND4 .GPD

Drainage Area	(acres)	49.3	--->	0.0770 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	1.48		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	0.5 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	265	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	38	0	0

Summary of Computations for qu

		Storm #1	Storm #2	Storm #3
Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	277.807	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	226.956	0.000	0.000
* qu (csm)		265	0	0

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
  If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND 4 - RETENTION POND
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND4 .DET

Drainage Area	(acres)	49.3	0.0770 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	4.7		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	8.8	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	6.0	0.0	0.0

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

APPENDIX C

ROUTING CALCULATIONS UNDER NORMAL CONDITIONS

PEAK1.XLS

TABLE D-4
POND ROUTING UNDER EXTREME CONDITIONS
POND 4 (RETENTION POND- SOUTHWEST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM
FEMP

Initial Pond Storage 2.55E+06 ft^3 Initial Pond Elevation 560.00 feet
Time Step= 360 second
Pond Overflow El.= 560 feet
Weir Width = 20 feet

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0	0	0	0.0	0	2.55E+06	560.00
11.1	6	1	0	360	0.0	4	2.55E+06	560.00
11.2	6	1	0	360	0.0	7	2.55E+06	560.01
11.3	6	1	0	360	0.0	11	2.55E+06	560.01
11.4	6	1	0	360	0.0	15	2.55E+06	560.01
11.5	6	2	0	720	0.1	20	2.55E+06	560.01
11.6	6	2	0	720	0.1	30	2.55E+06	560.01
11.7	6	2	0	720	0.1	42	2.55E+06	560.02
11.8	6	2	0	720	0.2	54	2.55E+06	560.02
11.9	6	2	0	720	0.2	68	2.55E+06	560.02
12	6	3	0	1080	0.2	82	2.56E+06	560.03
12.1	6	3	0	1080	0.3	105	2.56E+06	560.03
12.2	6	4	0	1440	0.4	129	2.56E+06	560.04
12.3	6	7	0	2520	0.5	164	2.56E+06	560.05
12.4	6	10	0	3600	0.7	234	2.56E+06	560.06
12.5	6	14	0	5040	1.0	347	2.57E+06	560.08
12.6	6	19	0	6840	1.5	529	2.57E+06	560.11
12.7	6	23	0	8280	2.2	809	2.58E+06	560.14
12.8	6	29	0	10440	3.3	1189	2.59E+06	560.17
12.9	6	33	0	11880	4.8	1722	2.60E+06	560.22
13	6	37	0	13320	6.6	2378	2.61E+06	560.26
13.1	6	40	0	14400	8.8	3160	2.62E+06	560.31
13.2	6	43	0	15480	11.2	4037	2.64E+06	560.35
13.3	6	42	0	15120	13.9	5000	2.65E+06	560.40
13.4	6	41	0	14760	16.4	5908	2.65E+06	560.43
13.5	6	38	0	13680	18.7	6742	2.66E+06	560.46
13.6	6	35	0	12600	20.6	7421	2.67E+06	560.48
13.7	6	32	0	11520	22.1	7942	2.67E+06	560.50
13.8	6	28	0	10080	23.1	8308	2.67E+06	560.50
13.9	6	26	0	9360	23.6	8492	2.67E+06	560.51
14	6	23	0	8280	23.8	8582	2.67E+06	560.51
14.1	6	21	0	7560	23.8	8551	2.67E+06	560.50
14.2	6	19	0	6840	23.5	8448	2.67E+06	560.50

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.3	6	17	0	6120	23.0	8281	2.67E+06	560.49
14.4	6	16	0	5760	22.4	8060	2.67E+06	560.48
14.5	6	14	0	5040	21.7	7826	2.66E+06	560.47
14.6	6	13	0	4680	21.0	7545	2.66E+06	560.45
14.7	6	12	0	4320	20.2	7261	2.66E+06	560.44
14.8	6	12	0	4320	19.4	6973	2.65E+06	560.43
14.9	6	11	0	3960	18.7	6716	2.65E+06	560.42
15	6	10	0	3600	17.9	6453	2.65E+06	560.41
15.1	6	9	0	3240	17.2	6184	2.65E+06	560.40
15.2	6	9	0	3240	16.4	5910	2.64E+06	560.38
15.3	6	8	0	2880	15.7	5666	2.64E+06	560.37
15.4	6	8	0	2880	15.0	5415	2.64E+06	560.36
15.5	6	7	0	2520	14.4	5190	2.63E+06	560.35
15.6	6	7	0	2520	13.8	4956	2.63E+06	560.34
15.7	6	7	0	2520	13.2	4746	2.63E+06	560.33
15.8	6	6	0	2160	12.7	4556	2.63E+06	560.32
15.9	6	6	0	2160	12.1	4355	2.63E+06	560.31
16	6	6	0	2160	11.6	4174	2.62E+06	560.[illegible]
16.1	6	6	0	2160	11.1	4010	2.62E+06	560[illegible]
16.2	6	6	0	2160	10.7	3861	2.62E+06	560.29
16.3	6	5	0	1800	10.3	3726	2.62E+06	560.28
16.4	6	5	0	1800	9.9	3575	2.62E+06	560.28
16.5	6	5	0	1800	9.5	3437	2.61E+06	560.27
16.6	6	5	0	1800	9.2	3312	2.61E+06	560.26
16.7	6	5	0	1800	8.9	3198	2.61E+06	560.26
16.8	6	5	0	1800	8.6	3093	2.61E+06	560.25
16.9	6	5	0	1800	8.3	2998	2.61E+06	560.25
17	6	5	0	1800	8.1	2910	2.61E+06	560.24
17.1	6	5	0	1800	7.9	2830	2.61E+06	560.24
17.2	6	5	0	1800	7.7	2756	2.61E+06	560.23
17.3	6	4	0	1440	7.5	2688	2.60E+06	560.23
17.4	6	4	0	1440	7.2	2600	2.60E+06	560.22
17.5	6	4	0	1440	7.0	2519	2.60E+06	560.22
17.6	6	4	0	1440	6.8	2445	2.60E+06	560.22
17.7	6	4	0	1440	6.6	2376	2.60E+06	560.21
17.8	6	4	0	1440	6.4	2313	2.60E+06	560.21
17.9	6	4	0	1440	6.3	2254	2.60E+06	560.20
18	6	4	0	1440	6.1	2200	2.60E+06	560.20
18.1	6	4	0	1440	6.0	2150	2.60E+06	560.20
18.2	6	4	0	1440	5.8	2103	2.60E+06	560.20
18.3	6	4	0	1440	5.7	2060	2.60E+06	560.19
18.4	6	4	0	1440	5.6	2020	2.60E+06	560[illegible]
18.5	6	4	0	1440	5.5	1983	2.60E+06	560.[illegible]
18.6	6	4	0	1440	5.4	1948	2.59E+06	560.19
18.7	6	4	0	1440	5.3	1916	2.59E+06	560.18

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.3	6	3	1080	8.5	3069	2.19E+06	578.64
23.4	6	3	1080	8.4	3034	2.19E+06	578.63
23.5	6	3	1080	8.3	2999	2.18E+06	578.63
23.6	6	3	1080	8.2	2965	2.18E+06	578.62
23.7	6	3	1080	8.1	2932	2.18E+06	578.62
23.8	6	3	1080	8.1	2900	2.18E+06	578.62
23.9	6	3	1080	8.0	2868	2.18E+06	578.61
24	6	2	720	7.9	2837	2.17E+06	578.61
24.1	6	2	720	7.8	2800	2.17E+06	578.60
24.2	6	2	720	7.7	2764	2.17E+06	578.60
24.3	6	2	720	7.6	2729	2.17E+06	578.59
24.4	6	2	720	7.5	2695	2.17E+06	578.59
24.5	6	2	720	7.4	2661	2.16E+06	578.58
24.6	6	2	720	7.3	2628	2.16E+06	578.58
24.7	6	2	720	7.2	2596	2.16E+06	578.57
24.8	6	2	720	7.1	2565	2.16E+06	578.57
24.9	6	1	360	7.0	2534	2.16E+06	578.56
25	6	1	360	6.9	2497	2.15E+06	578.56
25.1	6	1	360	6.8	2462	2.15E+06	578.55
25.2	6	1	360	6.7	2427	2.15E+06	578.55
25.3	6	1	360	6.6	2393	2.15E+06	578.54
25.4	6	1	360	6.6	2360	2.15E+06	578.54
25.5	6	1	360	6.5	2327	2.14E+06	578.53
25.6	6	0	0	6.4	2296	2.14E+06	578.52
26.5	60	0	0	6.4	22956	2.12E+06	578.47
31.5	300	0	0	5.4	96731	2.02E+06	578.23
36.5	300	0	0	1.8	33273	1.99E+06	578.15
41.5	300	0	0	1.0	17168	1.97E+06	578.11
46.5	300	0	0	0.6	10356	1.96E+06	578.08
51.5	300	0	0	0.4	6838	1.96E+06	578.06
61.5	600	0	0	0.3	9594	1.95E+06	578.04
71.5	600	0	0	0.1	4751	1.94E+06	578.03
81.5	600	0	0	0.1	2807	1.94E+06	578.02
91.5	600	0	0	0.1	1829	1.94E+06	578.02
101.5	600	0	0	0.0	1271	1.94E+06	578.01
111.5	600	0	0	0.0	926	1.94E+06	578.01
121.5	600	0	0	0.0	698	1.93E+06	578.01

Total volume of flow (ft^3) Inflow = 7.87E+05 Outflow= 7.45E+05

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	7	2520	13.5	4846	2.28E+06	578.87
18.9	6	7	2520	13.3	4798	2.28E+06	578.86
19	6	7	2520	13.2	4751	2.27E+06	578.86
19.1	6	7	2520	13.1	4705	2.27E+06	578.85
19.2	6	7	2520	12.9	4661	2.27E+06	578.85
19.3	6	6	2160	12.8	4617	2.27E+06	578.84
19.4	6	6	2160	12.7	4567	2.27E+06	578.83
19.5	6	6	2160	12.5	4518	2.26E+06	578.83
19.6	6	6	2160	12.4	4470	2.26E+06	578.82
19.7	6	6	2160	12.3	4424	2.26E+06	578.82
19.8	6	5	1800	12.2	4378	2.26E+06	578.81
19.9	6	5	1800	12.0	4327	2.25E+06	578.80
20	6	5	1800	11.9	4276	2.25E+06	578.80
20.1	6	5	1800	11.7	4227	2.25E+06	578.79
20.2	6	5	1800	11.6	4179	2.25E+06	578.79
20.3	6	5	1800	11.5	4132	2.24E+06	578.78
20.4	6	5	1800	11.4	4086	2.24E+06	578.77
20.5	6	5	1800	11.2	4042	2.24E+06	578.77
20.6	6	5	1800	11.1	3998	2.24E+06	578.7[illegible]
20.7	6	5	1800	11.0	3955	2.24E+06	578.76
20.8	6	5	1800	10.9	3914	2.23E+06	578.75
20.9	6	5	1800	10.8	3873	2.23E+06	578.75
21	6	5	1800	10.6	3833	2.23E+06	578.74
21.1	6	5	1800	10.5	3794	2.23E+06	578.74
21.2	6	5	1800	10.4	3756	2.22E+06	578.73
21.3	6	5	1800	10.3	3719	2.22E+06	578.73
21.4	6	5	1800	10.2	3682	2.22E+06	578.72
21.5	6	5	1800	10.1	3647	2.22E+06	578.72
21.6	6	5	1800	10.0	3612	2.22E+06	578.71
21.7	6	5	1800	9.9	3578	2.22E+06	578.71
21.8	6	5	1800	9.8	3545	2.21E+06	578.70
21.9	6	5	1800	9.8	3512	2.21E+06	578.70
22	6	5	1800	9.7	3480	2.21E+06	578.70
22.1	6	5	1800	9.6	3449	2.21E+06	578.69
22.2	6	5	1800	9.5	3419	2.21E+06	578.69
22.3	6	5	1800	9.4	3389	2.21E+06	578.68
22.4	6	4	1440	9.3	3360	2.20E+06	578.68
22.5	6	4	1440	9.2	3324	2.20E+06	578.67
22.6	6	4	1440	9.1	3290	2.20E+06	578.67
22.7	6	4	1440	9.0	3256	2.20E+06	578.67
22.8	6	4	1440	9.0	3223	2.20E+06	578.66
22.9	6	4	1440	8.9	3191	2.19E+06	578.6[illegible]
23	6	4	1440	8.8	3160	2.19E+06	578.6[illegible]
23.1	6	4	1440	8.7	3129	2.19E+06	578.65
23.2	6	4	1440	8.6	3099	2.19E+06	578.64

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POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.3	6	24	8640	17.7	6366	2.35E+06	579.05
14.4	6	23	8280	17.8	6417	2.36E+06	579.06
14.5	6	21	7560	17.9	6460	2.36E+06	579.06
14.6	6	20	7200	18.0	6485	2.36E+06	579.06
14.7	6	19	6840	18.1	6501	2.36E+06	579.06
14.8	6	18	6480	18.1	6509	2.36E+06	579.06
14.9	6	16	5760	18.1	6508	2.36E+06	579.06
15	6	15	5400	18.0	6491	2.36E+06	579.06
15.1	6	15	5400	18.0	6466	2.35E+06	579.06
15.2	6	14	5040	17.9	6442	2.35E+06	579.05
15.3	6	14	5040	17.8	6410	2.35E+06	579.05
15.4	6	13	4680	17.7	6379	2.35E+06	579.04
15.5	6	13	4680	17.6	6340	2.35E+06	579.04
15.6	6	13	4680	17.5	6303	2.35E+06	579.04
15.7	6	13	4680	17.4	6266	2.35E+06	579.03
15.8	6	12	4320	17.3	6230	2.34E+06	579.03
15.9	6	12	4320	17.2	6187	2.34E+06	579.02
16	6	12	4320	17.1	6145	2.34E+06	579.02
16.1	6	12	4320	17.0	6104	2.34E+06	579.01
16.2	6	11	3960	16.8	6064	2.34E+06	579.01
16.3	6	11	3960	16.7	6017	2.33E+06	579.00
16.4	6	10	3600	16.6	5972	2.33E+06	579.00
16.5	6	10	3600	16.4	5919	2.33E+06	578.99
16.6	6	10	3600	16.3	5868	2.33E+06	578.99
16.7	6	10	3600	16.2	5818	2.32E+06	578.98
16.8	6	9	3240	16.0	5769	2.32E+06	578.97
16.9	6	9	3240	15.9	5713	2.32E+06	578.97
17	6	9	3240	15.7	5659	2.32E+06	578.96
17.1	6	9	3240	15.6	5606	2.32E+06	578.96
17.2	6	9	3240	15.4	5555	2.31E+06	578.95
17.3	6	9	3240	15.3	5505	2.31E+06	578.94
17.4	6	9	3240	15.2	5456	2.31E+06	578.94
17.5	6	9	3240	15.0	5408	2.31E+06	578.93
17.6	6	9	3240	14.9	5361	2.30E+06	578.93
17.7	6	9	3240	14.8	5316	2.30E+06	578.92
17.8	6	9	3240	14.6	5272	2.30E+06	578.92
17.9	6	9	3240	14.5	5228	2.30E+06	578.91
18	6	9	3240	14.4	5186	2.30E+06	578.91
18.1	6	9	3240	14.3	5145	2.29E+06	578.90
18.2	6	9	3240	14.2	5105	2.29E+06	578.90
18.3	6	8	2880	14.1	5065	2.29E+06	578.89
18.4	6	8	2880	13.9	5019	2.29E+06	578.89
18.5	6	8	2880	13.8	4975	2.29E+06	578.88
18.6	6	8	2880	13.7	4931	2.28E+06	578.88
18.7	6	8	2880	13.6	4888	2.28E+06	578.87

TABLE D-3
POND ROUTING UNDER EXTREME CONDITIONS
POND 3 (SOUTHEAST OF FEMP, BORROWED AREA)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage 1.93E+06 ft^3 Initial Pond Elevation 578.00 feet
Time Step= 360 second
Pond Overflow El.= 578 feet Pond 3 overflow to SSOD
Weir Width = 5 feet

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0		0.0	0	1.93E+06	578.00
11.1	6	3	1080	0.0	0	1.93E+06	578.00
11.2	6	4	1440	0.0	0	1.93E+06	578.00
11.3	6	4	1440	0.0	1	1.93E+06	578.01
11.4	6	5	1800	0.0	3	1.94E+06	578.01
11.5	6	5	1800	0.0	7	1.94E+06	578.02
11.6	6	6	2160	0.0	12	1.94E+06	578.02
11.7	6	7	2520	0.1	18	1.94E+06	578.03
11.8	6	7	2520	0.1	27	1.94E+06	578.03
11.9	6	8	2880	0.1	37	1.95E+06	578.04
12	6	12	4320	0.1	49	1.95E+06	578.05
12.1	6	20	7200	0.2	69	1.96E+06	578.07
12.2	6	32	11520	0.3	108	1.97E+06	578.10
12.3	6	53	19080	0.5	181	1.99E+06	578.14
12.4	6	72	25920	0.9	327	2.01E+06	578.21
12.5	6	87	31320	1.6	565	2.05E+06	578.29
12.6	6	93	33480	2.5	904	2.08E+06	578.37
12.7	6	94	33840	3.7	1316	2.11E+06	578.45
12.8	6	95	34200	4.9	1777	2.14E+06	578.53
12.9	6	92	33120	6.3	2279	2.17E+06	578.60
13	6	90	32400	7.8	2794	2.20E+06	578.68
13.1	6	82	29520	9.2	3321	2.23E+06	578.74
13.2	6	75	27000	10.6	3811	2.25E+06	578.80
13.3	6	67	24120	11.8	4263	2.27E+06	578.85
13.4	6	60	21600	13.0	4664	2.29E+06	578.89
13.5	6	54	19440	13.9	5015	2.30E+06	578.93
13.6	6	47	16920	14.8	5321	2.32E+06	578.96
13.7	6	42	15120	15.5	5571	2.33E+06	578.98
13.8	6	37	13320	16.1	5780	2.33E+06	579.00
13.9	6	34	12240	16.5	5946	2.34E+06	579.02
14	6	31	11160	16.9	6087	2.34E+06	579.0[illegible]
14.1	6	29	10440	17.2	6200	2.35E+06	579.04
14.2	6	26	9360	17.5	6296	2.35E+06	579.05

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POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.2	6	4	1440	0.0	0	6.75E+06	567.64
23.3	6	3	1080	0.0	0	6.76E+06	567.64
23.4	6	3	1080	0.0	0	6.76E+06	567.65
23.5	6	3	1080	0.0	0	6.76E+06	567.65
23.6	6	3	1080	0.0	0	6.76E+06	567.65
23.7	6	3	1080	0.0	0	6.76E+06	567.65
23.8	6	3	1080	0.0	0	6.76E+06	567.65
23.9	6	3	1080	0.0	0	6.76E+06	567.65
24	6	2	720	0.0	0	6.76E+06	567.66
24.1	6	2	720	0.0	0	6.76E+06	567.66
24.2	6	2	720	0.0	0	6.76E+06	567.66
24.3	6	2	720	0.0	0	6.76E+06	567.66
24.4	6	2	720	0.0	0	6.77E+06	567.66
24.5	6	2	720	0.0	0	6.77E+06	567.66
24.6	6	2	720	0.0	0	6.77E+06	567.66
24.7	6	2	720	0.0	0	6.77E+06	567.66
24.8	6	2	720	0.0	0	6.77E+06	567.67
24.9	6	1	360	0.0	0	6.77E+06	567.67
25	6	1	360	0.0	0	6.77E+06	567.67
25.1	6	1	360	0.0	0	6.77E+06	567.67
25.2	6	1	360	0.0	0	6.77E+06	567.67
25.3	6	1	360	0.0	0	6.77E+06	567.67
25.4	6	1	360	0.0	0	6.77E+06	567.67
25.5	6	1	360	0.0	0	6.77E+06	567.67
30.5	300	0	0	0.0	0	6.77E+06	567.67
35.5	300	0	0	0.0	0	6.77E+06	567.67
40.5	300	0	0	0.0	0	6.77E+06	567.67
45.5	300	0	0	0.0	0	6.77E+06	567.67
50.5	300	0	0	0.0	0	6.77E+06	567.67
55.5	300	0	0	0.0	0	6.77E+06	567.67
65.5	600	0	0	0.0	0	6.77E+06	567.67
75.5	600	0	0	0.0	0	6.77E+06	567.67
85.5	600	0	0	0.0	0	6.77E+06	567.67
95.5	600	0	0	0.0	0	6.77E+06	567.67
105.5	600	0	0	0.0	0	6.77E+06	567.67
115.5	600	0	0	0.0	0	6.77E+06	567.67
125.5	600	0	0	0.0	0	6.77E+06	567.67

Total volume of flow (ft^3) Inflow = 8.11E+05 Outflow = 0.00E+00

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.7	6	7	2520	0.0	0	6.67E+06	567.50
18.8	6	7	2520	0.0	0	6.67E+06	567.50
18.9	6	7	2520	0.0	0	6.67E+06	567.50
19	6	7	2520	0.0	0	6.67E+06	567.51
19.1	6	7	2520	0.0	0	6.68E+06	567.51
19.2	6	7	2520	0.0	0	6.68E+06	567.52
19.3	6	7	2520	0.0	0	6.68E+06	567.52
19.4	6	7	2520	0.0	0	6.68E+06	567.53
19.5	6	6	2160	0.0	0	6.69E+06	567.53
19.6	6	6	2160	0.0	0	6.69E+06	567.53
19.7	6	6	2160	0.0	0	6.69E+06	567.54
19.8	6	6	2160	0.0	0	6.69E+06	567.54
19.9	6	6	2160	0.0	0	6.69E+06	567.54
20	6	6	2160	0.0	0	6.70E+06	567.55
20.1	6	6	2160	0.0	0	6.70E+06	567.55
20.2	6	6	2160	0.0	0	6.70E+06	567.55
20.3	6	6	2160	0.0	0	6.70E+06	567.56
20.4	6	6	2160	0.0	0	6.70E+06	567.56
20.5	6	6	2160	0.0	0	6.71E+06	567.56
20.6	6	6	2160	0.0	0	6.71E+06	567.57
20.7	6	6	2160	0.0	0	6.71E+06	567.57
20.8	6	6	2160	0.0	0	6.71E+06	567.58
20.9	6	6	2160	0.0	0	6.72E+06	567.58
21	6	6	2160	0.0	0	6.72E+06	567.58
21.1	6	5	1800	0.0	0	6.72E+06	567.59
21.2	6	5	1800	0.0	0	6.72E+06	567.59
21.3	6	5	1800	0.0	0	6.72E+06	567.59
21.4	6	5	1800	0.0	0	6.73E+06	567.59
21.5	6	5	1800	0.0	0	6.73E+06	567.60
21.6	6	5	1800	0.0	0	6.73E+06	567.60
21.7	6	5	1800	0.0	0	6.73E+06	567.60
21.8	6	5	1800	0.0	0	6.73E+06	567.61
21.9	6	5	1800	0.0	0	6.73E+06	567.61
22	6	5	1800	0.0	0	6.74E+06	567.61
22.1	6	5	1800	0.0	0	6.74E+06	567.61
22.2	6	5	1800	0.0	0	6.74E+06	567.62
22.3	6	5	1800	0.0	0	6.74E+06	567.62
22.4	6	4	1440	0.0	0	6.74E+06	567.62
22.5	6	4	1440	0.0	0	6.74E+06	567.63
22.6	6	4	1440	0.0	0	6.75E+06	567.63
22.7	6	4	1440	0.0	0	6.75E+06	567.63
22.8	6	4	1440	0.0	0	6.75E+06	567.63
22.9	6	4	1440	0.0	0	6.75E+06	567.64
23	6	4	1440	0.0	0	6.75E+06	567.64
23.1	6	4	1440	0.0	0	6.75E+06	567.64

PEAK1.XLS

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft³/sec)	Inflow Volume I*dt (ft³)	Outflow from Weir O (ft³/sec)	Outflow Volume O*dt (ft³)	Pond Storage S (ft³)	Pond Stage (ft)
14.2	6	32	11520	0.0	0	6.45E+06	567.15
14.3	6	29	10440	0.0	0	6.46E+06	567.16
14.4	6	27	9720	0.0	0	6.47E+06	567.18
14.5	6	26	9360	0.0	0	6.48E+06	567.19
14.6	6	24	8640	0.0	0	6.49E+06	567.21
14.7	6	23	8280	0.0	0	6.50E+06	567.22
14.8	6	22	7920	0.0	0	6.51E+06	567.24
14.9	6	20	7200	0.0	0	6.51E+06	567.25
15	6	19	6840	0.0	0	6.52E+06	567.26
15.1	6	18	6480	0.0	0	6.53E+06	567.27
15.2	6	17	6120	0.0	0	6.53E+06	567.28
15.3	6	17	6120	0.0	0	6.54E+06	567.29
15.4	6	16	5760	0.0	0	6.55E+06	567.30
15.5	6	15	5400	0.0	0	6.55E+06	567.31
15.6	6	15	5400	0.0	0	6.56E+06	567.32
15.7	6	14	5040	0.0	0	6.56E+06	567.32
15.8	6	14	5040	0.0	0	6.57E+06	567.33
15.9	6	13	4680	0.0	0	6.57E+06	567.34
16	6	13	4680	0.0	0	6.58E+06	567.35
16.1	6	13	4680	0.0	0	6.58E+06	567.36
16.2	6	12	4320	0.0	0	6.58E+06	567.36
16.3	6	12	4320	0.0	0	6.59E+06	567.37
16.4	6	11	3960	0.0	0	6.59E+06	567.38
16.5	6	11	3960	0.0	0	6.60E+06	567.38
16.6	6	11	3960	0.0	0	6.60E+06	567.39
16.7	6	10	3600	0.0	0	6.60E+06	567.40
16.8	6	10	3600	0.0	0	6.61E+06	567.40
16.9	6	9	3240	0.0	0	6.61E+06	567.41
17	6	9	3240	0.0	0	6.61E+06	567.41
17.1	6	9	3240	0.0	0	6.62E+06	567.42
17.2	6	9	3240	0.0	0	6.62E+06	567.42
17.3	6	9	3240	0.0	0	6.62E+06	567.43
17.4	6	9	3240	0.0	0	6.63E+06	567.43
17.5	6	9	3240	0.0	0	6.63E+06	567.44
17.6	6	9	3240	0.0	0	6.63E+06	567.44
17.7	6	9	3240	0.0	0	6.64E+06	567.45
17.8	6	8	2880	0.0	0	6.64E+06	567.45
17.9	6	8	2880	0.0	0	6.64E+06	567.46
18	6	8	2880	0.0	0	6.65E+06	567.46
18.1	6	8	2880	0.0	0	6.65E+06	567.47
18.2	6	8	2880	0.0	0	6.65E+06	567.47
18.3	6	8	2880	0.0	0	6.65E+06	567.48
18.4	6	8	2880	0.0	0	6.66E+06	567.48
18.5	6	8	2880	0.0	0	6.66E+06	567.49
18.6	6	7	2520	0.0	0	6.66E+06	567.49

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.3	6	1	0	360	2.4	869	2.58E+06	560.11
23.4	6	1	0	360	2.3	845	2.58E+06	560.11
23.5	6	1	0	360	2.3	822	2.57E+06	560.10
23.6	6	1	0	360	2.2	800	2.57E+06	560.10
23.7	6	1	0	360	2.2	779	2.57E+06	560.10
23.8	6	1	0	360	2.1	759	2.57E+06	560.10
23.9	6	1	0	360	2.1	741	2.57E+06	560.10
24	6	1	0	360	2.0	723	2.57E+06	560.10
24.1	6	1	0	360	2.0	707	2.57E+06	560.09
24.2	6	1	0	360	1.9	691	2.57E+06	560.09
24.3	6	1	0	360	1.9	676	2.57E+06	560.09
24.4	6	1	0	360	1.8	662	2.57E+06	560.09
24.5	6	1	0	360	1.8	649	2.57E+06	560.09
24.6	6	1	0	360	1.8	636	2.57E+06	560.09
24.7	6	1	0	360	1.7	624	2.57E+06	560.09
24.8	6	1	0	360	1.7	613	2.57E+06	560.09
24.9	6	1	0	360	1.7	602	2.57E+06	560.09
25	6	0	0	0	1.6	591	2.57E+06	560.[illegible]
25.1	6	0	0	0	1.6	566	2.57E+06	560[illegible]
25.2	6	0	0	0	1.5	542	2.57E+06	560.08
25.3	6	0	0	0	1.4	520	2.57E+06	560.08
25.4	6	0	0	0	1.4	499	2.57E+06	560.07
25.5	6	0	0	0	1.3	479	2.57E+06	560.07
25.6	6	0	0	0	1.3	460	2.57E+06	560.07
26.5	54	0	0	0	1.2	3977	2.56E+06	560.05
31.5	300	0	0	0	0.8	14844	2.55E+06	559.99
36.5	300	0	0	0	0.0	0	2.55E+06	559.99
41.5	300	0	0	0	0.0	0	2.55E+06	559.99
46.5	300	0	0	0	0.0	0	2.55E+06	559.99
51.5	300	0	0	0	0.0	0	2.55E+06	559.99
61.5	600	0	0	0	0.0	0	2.55E+06	559.99
71.5	600	0	0	0	0.0	0	2.55E+06	559.99
81.5	600	0	0	0	0.0	0	2.55E+06	559.99
91.5	600	0	0	0	0.0	0	2.55E+06	559.99
101.5	600	0	0	0	0.0	0	2.55E+06	559.99
111.5	600	0	0	0	0.0	0	2.55E+06	559.99
121.5	600	0	0	0	0.0	0	2.55E+06	559.99
Total volume of flow (ft^3)=		Inflow =		3.67E+05	Outflow	3.69E+05		

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PEAK1.XLS

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	4	0	1440	5.2	1886	2.59E+06	560.18
18.9	6	4	0	1440	5.2	1858	2.59E+06	560.18
19	6	4	0	1440	5.1	1832	2.59E+06	560.18
19.1	6	4	0	1440	5.0	1807	2.59E+06	560.18
19.2	6	4	0	1440	5.0	1784	2.59E+06	560.18
19.3	6	4	0	1440	4.9	1763	2.59E+06	560.18
19.4	6	4	0	1440	4.8	1743	2.59E+06	560.17
19.5	6	4	0	1440	4.8	1725	2.59E+06	560.17
19.6	6	3	0	1080	4.7	1707	2.59E+06	560.17
19.7	6	3	0	1080	4.6	1669	2.59E+06	560.17
19.8	6	3	0	1080	4.5	1634	2.59E+06	560.17
19.9	6	3	0	1080	4.4	1601	2.59E+06	560.16
20	6	3	0	1080	4.4	1570	2.59E+06	560.16
20.1	6	3	0	1080	4.3	1541	2.59E+06	560.16
20.2	6	3	0	1080	4.2	1514	2.59E+06	560.16
20.3	6	3	0	1080	4.1	1488	2.59E+06	560.16
20.4	6	3	0	1080	4.1	1465	2.59E+06	560.15
20.5	6	3	0	1080	4.0	1443	2.59E+06	560.15
20.6	6	3	0	1080	3.9	1422	2.59E+06	560.15
20.7	6	3	0	1080	3.9	1402	2.59E+06	560.15
20.8	6	3	0	1080	3.8	1384	2.59E+06	560.15
20.9	6	3	0	1080	3.8	1367	2.59E+06	560.15
21	6	2	0	720	3.8	1350	2.58E+06	560.15
21.1	6	2	0	720	3.7	1315	2.58E+06	560.14
21.2	6	2	0	720	3.6	1282	2.58E+06	560.14
21.3	6	2	0	720	3.5	1251	2.58E+06	560.14
21.4	6	2	0	720	3.4	1222	2.58E+06	560.14
21.5	6	2	0	720	3.3	1195	2.58E+06	560.13
21.6	6	2	0	720	3.2	1169	2.58E+06	560.13
21.7	6	2	0	720	3.2	1145	2.58E+06	560.13
21.8	6	2	0	720	3.1	1122	2.58E+06	560.13
21.9	6	2	0	720	3.1	1101	2.58E+06	560.13
22	6	2	0	720	3.0	1081	2.58E+06	560.13
22.1	6	2	0	720	3.0	1062	2.58E+06	560.12
22.2	6	2	0	720	2.9	1045	2.58E+06	560.12
22.3	6	2	0	720	2.9	1028	2.58E+06	560.12
22.4	6	2	0	720	2.8	1012	2.58E+06	560.12
22.5	6	2	0	720	2.8	997	2.58E+06	560.12
22.6	6	2	0	720	2.7	983	2.58E+06	560.12
22.7	6	2	0	720	2.7	970	2.58E+06	560.12
22.8	6	2	0	720	2.7	957	2.58E+06	560.12
22.9	6	2	0	720	2.6	945	2.58E+06	560.12
23	6	2	0	720	2.6	934	2.58E+06	560.11
23.1	6	1	0	360	2.6	923	2.58E+06	560.11
23.2	6	1	0	360	2.5	896	2.58E+06	560.11

TABLE D-2
POND ROUTING UNDER EXTREME CONDITIONS
POND 2 (NORTHWEST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage 5.96E+06 ft^3   Initial Pond Elevation 566.33 feet
Time Step= 360 second
Pond Overflow El.= 573 feet
Weir Width = 5 feet

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
10.9		0		0.0	0	5.96E+06	566.33
11	6	2	720	0.0	0	5.96E+06	566.33
11.1	6	3	1080	0.0	0	5.96E+06	566.34
11.2	6	3	1080	0.0	0	5.96E+06	566.34
11.3	6	4	1440	0.0	0	5.96E+06	566.34
11.4	6	4	1440	0.0	0	5.97E+06	566.34
11.5	6	4	1440	0.0	0	5.97E+06	566.34
11.6	6	4	1440	0.0	0	5.97E+06	566.35
11.7	6	5	1800	0.0	0	5.97E+06	566.35
11.8	6	5	1800	0.0	0	5.97E+06	566.35
11.9	6	6	2160	0.0	0	5.97E+06	566.36
12	6	7	2520	0.0	0	5.98E+06	566.36
12.1	6	8	2880	0.0	0	5.98E+06	566.37
12.2	6	10	3600	0.0	0	5.98E+06	566.37
12.3	6	15	5400	0.0	0	5.99E+06	566.38
12.4	6	22	7920	0.0	0	6.00E+06	566.39
12.5	6	36	12960	0.0	0	6.01E+06	566.41
12.6	6	54	19440	0.0	0	6.03E+06	566.45
12.7	6	77	27720	0.0	0	6.06E+06	566.49
12.8	6	98	35280	0.0	0	6.09E+06	566.55
12.9	6	108	38880	0.0	0	6.13E+06	566.61
13	6	117	42120	0.0	0	6.17E+06	566.68
13.1	6	112	40320	0.0	0	6.21E+06	566.75
13.2	6	107	38520	0.0	0	6.25E+06	566.81
13.3	6	94	33840	0.0	0	6.29E+06	566.87
13.4	6	82	29520	0.0	0	6.32E+06	566.92
13.5	6	72	25920	0.0	0	6.34E+06	566.96
13.6	6	62	22320	0.0	0	6.36E+06	567.00
13.7	6	54	19440	0.0	0	6.38E+06	567.03
13.8	6	47	16920	0.0	0	6.40E+06	567.06
13.9	6	42	15120	0.0	0	6.42E+06	567.08
14	6	38	13680	0.0	0	6.43E+06	567.11
14.1	6	35	12600	0.0	0	6.44E+06	567.13

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.3	6	3	1080	10.4	3727	4.82E+06	573.73
23.4	6	3	1080	10.2	3688	4.82E+06	573.72
23.5	6	3	1080	10.1	3650	4.82E+06	573.72
23.6	6	3	1080	10.0	3613	4.82E+06	573.71
23.7	6	3	1080	9.9	3576	4.81E+06	573.71
23.8	6	3	1080	9.8	3540	4.81E+06	573.70
23.9	6	3	1080	9.7	3505	4.81E+06	573.70
24	6	2	720	9.6	3470	4.81E+06	573.69
24.1	6	2	720	9.5	3431	4.80E+06	573.69
24.2	6	2	720	9.4	3393	4.80E+06	573.68
24.3	6	2	720	9.3	3355	4.80E+06	573.68
24.4	6	2	720	9.2	3318	4.80E+06	573.67
24.5	6	2	720	9.1	3281	4.79E+06	573.67
24.6	6	2	720	9.0	3245	4.79E+06	573.66
24.7	6	2	720	8.9	3210	4.79E+06	573.66
24.8	6	2	720	8.8	3175	4.79E+06	573.65
24.9	6	1	360	8.7	3141	4.78E+06	573.65
25	6	1	360	8.6	3103	4.78E+06	573.64
25.1	6	1	360	8.5	3065	4.78E+06	573.64
25.2	6	1	360	8.4	3028	4.78E+06	573.63
25.3	6	1	360	8.3	2992	4.77E+06	573.63
25.4	6	1	360	8.2	2956	4.77E+06	573.62
25.5	6	1	360	8.1	2921	4.77E+06	573.62
30.5	300	0	0	8.0	144340	4.62E+06	573.34
35.5	300	0	0	3.3	59220	4.56E+06	573.23
40.5	300	0	0	1.8	32275	4.53E+06	573.17
45.5	300	0	0	1.1	20055	4.51E+06	573.13
50.5	300	0	0	0.7	13499	4.50E+06	573.10
55.5	300	0	0	0.5	9600	4.49E+06	573.08
65.5	600	0	0	0.4	14218	4.47E+06	573.06
75.5	600	0	0	0.2	7827	4.47E+06	573.04
85.5	600	0	0	0.1	4891	4.46E+06	573.03
95.5	600	0	0	0.1	3304	4.46E+06	573.03
105.5	600	0	0	0.1	2356	4.46E+06	573.02
115.5	600	0	0	0.0	1748	4.45E+06	573.02
125.5	600	0	0	0.0	1338	4.45E+06	573.01

Total volume of flow (ft^3)= Inflow = 9.38E+05 Outflow 8.72E+05

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	8	2880	15.1	5435	4.93E+06	573.94
18.9	6	8	2880	15.0	5392	4.93E+06	573.93
19	6	8	2880	14.9	5351	4.93E+06	573.93
19.1	6	8	2880	14.8	5310	4.93E+06	573.92
19.2	6	8	2880	14.6	5270	4.92E+06	573.92
19.3	6	8	2880	14.5	5231	4.92E+06	573.91
19.4	6	8	2880	14.4	5192	4.92E+06	573.91
19.5	6	8	2880	14.3	5155	4.92E+06	573.91
19.6	6	7	2520	14.2	5118	4.91E+06	573.90
19.7	6	7	2520	14.1	5076	4.91E+06	573.90
19.8	6	7	2520	14.0	5034	4.91E+06	573.89
19.9	6	7	2520	13.9	4994	4.91E+06	573.89
20	6	7	2520	13.8	4954	4.90E+06	573.88
20.1	6	7	2520	13.7	4915	4.90E+06	573.88
20.2	6	7	2520	13.5	4876	4.90E+06	573.87
20.3	6	7	2520	13.4	4839	4.90E+06	573.87
20.4	6	7	2520	13.3	4802	4.90E+06	573.86
20.5	6	6	2160	13.2	4765	4.89E+06	573.86
20.6	6	6	2160	13.1	4724	4.89E+06	573.8[illegible]
20.7	6	6	2160	13.0	4683	4.89E+06	573.85
20.8	6	6	2160	12.9	4644	4.89E+06	573.84
20.9	6	6	2160	12.8	4605	4.88E+06	573.84
21	6	6	2160	12.7	4566	4.88E+06	573.83
21.1	6	6	2160	12.6	4529	4.88E+06	573.83
21.2	6	6	2160	12.5	4492	4.88E+06	573.83
21.3	6	6	2160	12.4	4456	4.87E+06	573.82
21.4	6	6	2160	12.3	4420	4.87E+06	573.82
21.5	6	6	2160	12.2	4385	4.87E+06	573.81
21.6	6	5	1800	12.1	4351	4.87E+06	573.81
21.7	6	5	1800	12.0	4311	4.86E+06	573.80
21.8	6	5	1800	11.9	4273	4.86E+06	573.80
21.9	6	5	1800	11.8	4235	4.86E+06	573.79
22	6	5	1800	11.7	4198	4.86E+06	573.79
22.1	6	5	1800	11.6	4162	4.85E+06	573.78
22.2	6	5	1800	11.5	4126	4.85E+06	573.78
22.3	6	5	1800	11.4	4091	4.85E+06	573.78
22.4	6	4	1440	11.3	4056	4.85E+06	573.77
22.5	6	4	1440	11.2	4017	4.84E+06	573.77
22.6	6	4	1440	11.1	3978	4.84E+06	573.76
22.7	6	4	1440	10.9	3940	4.84E+06	573.76
22.8	6	4	1440	10.8	3903	4.84E+06	573.75
22.9	6	4	1440	10.7	3867	4.83E+06	573.7[illegible]
23	6	4	1440	10.6	3831	4.83E+06	573.7[illegible]
23.1	6	4	1440	10.5	3795	4.83E+06	573.74
23.2	6	4	1440	10.4	3761	4.83E+06	573.73

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.3	6	31	11160	16.9	6085	4.98E+06	574.03
14.4	6	29	10440	17.1	6172	4.98E+06	574.03
14.5	6	26	9360	17.4	6246	4.99E+06	574.04
14.6	6	24	8640	17.5	6300	4.99E+06	574.04
14.7	6	23	8280	17.6	6341	4.99E+06	574.05
14.8	6	22	7920	17.7	6375	4.99E+06	574.05
14.9	6	20	7200	17.8	6402	4.99E+06	574.05
15	6	19	6840	17.8	6416	4.99E+06	574.05
15.1	6	18	6480	17.8	6424	4.99E+06	574.05
15.2	6	18	6480	17.8	6425	4.99E+06	574.05
15.3	6	17	6120	17.8	6426	4.99E+06	574.05
15.4	6	17	6120	17.8	6420	4.99E+06	574.05
15.5	6	16	5760	17.8	6415	4.99E+06	574.05
15.6	6	16	5760	17.8	6403	4.99E+06	574.05
15.7	6	16	5760	17.8	6392	4.99E+06	574.05
15.8	6	15	5400	17.7	6381	4.99E+06	574.05
15.9	6	15	5400	17.7	6364	4.99E+06	574.05
16	6	15	5400	17.6	6347	4.99E+06	574.04
16.1	6	15	5400	17.6	6331	4.99E+06	574.04
16.2	6	14	5040	17.5	6314	4.99E+06	574.04
16.3	6	14	5040	17.5	6292	4.99E+06	574.04
16.4	6	13	4680	17.4	6270	4.98E+06	574.03
16.5	6	13	4680	17.3	6243	4.98E+06	574.03
16.6	6	13	4680	17.3	6216	4.98E+06	574.03
16.7	6	12	4320	17.2	6189	4.98E+06	574.02
16.8	6	12	4320	17.1	6157	4.98E+06	574.02
16.9	6	11	3960	17.0	6125	4.98E+06	574.02
17	6	11	3960	16.9	6088	4.97E+06	574.01
17.1	6	11	3960	16.8	6051	4.97E+06	574.01
17.2	6	11	3960	16.7	6015	4.97E+06	574.00
17.3	6	11	3960	16.6	5980	4.97E+06	574.00
17.4	6	11	3960	16.5	5945	4.96E+06	574.00
17.5	6	11	3960	16.4	5911	4.96E+06	573.99
17.6	6	11	3960	16.3	5878	4.96E+06	573.99
17.7	6	10	3600	16.2	5845	4.96E+06	573.99
17.8	6	10	3600	16.1	5807	4.96E+06	573.98
17.9	6	10	3600	16.0	5770	4.95E+06	573.98
18	6	10	3600	15.9	5733	4.95E+06	573.97
18.1	6	10	3600	15.8	5697	4.95E+06	573.97
18.2	6	10	3600	15.7	5662	4.95E+06	573.96
18.3	6	9	3240	15.6	5627	4.95E+06	573.96
18.4	6	9	3240	15.5	5587	4.94E+06	573.96
18.5	6	9	3240	15.4	5548	4.94E+06	573.95
18.6	6	9	3240	15.3	5509	4.94E+06	573.95
18.7	6	9	3240	15.2	5472	4.94E+06	573.94

TABLE D-1
POND ROUTING UNDER EXTREME CONDITIONS
POND 1 (NORTHEAST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage 4.45E+06 ft^3   Initial Pond Elevation   573 feet
Time Step= 360 second
Pond Overflow El.= 573 feet
Weir Width = 5 feet

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0		0.0	0	4.45E+06	573.00
11.1	6	3	1080	0.0	0	4.45E+06	573.00
11.2	6	4	1440	0.0	1	4.45E+06	573.01
11.3	6	4	1440	0.0	2	4.45E+06	573.01
11.4	6	4	1440	0.0	4	4.45E+06	573.01
11.5	6	5	1800	0.0	7	4.45E+06	573.01
11.6	6	5	1800	0.0	10	4.45E+06	573.02
11.7	6	6	2160	0.0	14	4.46E+06	573.02
11.8	6	8	2880	0.1	19	4.46E+06	573.03
11.9	6	9	3240	0.1	27	4.46E+06	573.03
12	6	9	3240	0.1	36	4.47E+06	573.04
12.1	6	11	3960	0.1	47	4.47E+06	573.05
12.2	6	13	4680	0.2	61	4.47E+06	573.06
12.3	6	21	7560	0.2	78	4.48E+06	573.07
12.4	6	34	12240	0.3	111	4.49E+06	573.09
12.5	6	57	20520	0.5	170	4.51E+06	573.13
12.6	6	83	29880	0.8	287	4.54E+06	573.19
12.7	6	109	39240	1.4	489	4.58E+06	573.26
12.8	6	125	45000	2.2	804	4.63E+06	573.35
12.9	6	127	45720	3.4	1221	4.67E+06	573.43
13	6	129	46440	4.7	1697	4.72E+06	573.52
13.1	6	122	43920	6.2	2224	4.76E+06	573.60
13.2	6	114	41040	7.7	2757	4.80E+06	573.67
13.3	6	103	37080	9.1	3279	4.83E+06	573.74
13.4	6	92	33120	10.5	3764	4.86E+06	573.79
13.5	6	82	29520	11.7	4203	4.88E+06	573.84
13.6	6	72	25920	12.8	4594	4.91E+06	573.88
13.7	6	63	22680	13.7	4933	4.92E+06	573.92
13.8	6	55	19800	14.5	5221	4.94E+06	573.95
13.9	6	49	17640	15.2	5461	4.95E+06	573.97
14	6	43	15480	15.7	5665	4.96E+06	573.99
14.1	6	39	14040	16.2	5831	4.97E+06	574.00
14.2	6	35	12600	16.6	5971	4.98E+06	574.02

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APPENDIX D

ROUTING CALCULATIONS UNDER EXTREME CONDITIONS

POND 4

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft^3)	Inflow from Pond 2 (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3/day)	Total Out flow O (ft^3)
3	30	3.59	4.83E+04	0.191	3.42E+04	0.00E+00	8.25E+04	558.37	1.62E+05	520	2.32E+06	4.79E-01	7.74E+04	6.098	8.21E+04	0.00E+00	1.59E+05
3	31	4.09	5.38E+04	0.473	8.46E+04	0.00E+00	1.38E+05	557.82	1.58E+05	520	2.25E+06	4.68E-01	7.38E+04	5.905	7.77E+04	0.00E+00	1.51E+05
3	32	2.8	3.67E+04	0.125	2.24E+04	0.00E+00	5.90E+04	557.73	1.57E+05	520	2.23E+06	4.66E-01	7.32E+04	5.039	6.60E+04	0.00E+00	1.39E+05
3	33	2.59	3.31E+04	0.087	1.56E+04	0.00E+00	4.87E+04	557.15	1.53E+05	520	2.15E+06	4.54E-01	6.96E+04	4.036	5.16E+04	0.00E+00	1.21E+05
3	34	2.11	2.64E+04	0.016	2.86E+03	0.00E+00	2.92E+04	556.63	1.50E+05	520	2.08E+06	4.43E-01	6.64E+04	2.593	3.24E+04	0.00E+00	9.88E+04
3	35	3.01	3.68E+04	0.057	1.02E+04	0.00E+00	4.70E+04	556.13	1.47E+05	520	2.01E+06	4.33E-01	6.35E+04	1.558	1.90E+04	0.00E+00	8.25E+04
3	36	2.86	3.45E+04	0.187	3.34E+04	0.00E+00	6.80E+04	555.87	1.45E+05	520	1.98E+06	4.28E-01	6.20E+04	0.494	5.97E+03	0.00E+00	6.79E+04
4	37	3.66	4.42E+04	1.242	2.22E+05	0.00E+00	2.66E+05	555.87	1.45E+05	520	1.98E+06	4.28E-01	6.20E+04	0.527	6.36E+03	0.00E+00	6.83E+04
4	38	2.98	3.83E+04	2.125	3.80E+05	0.00E+00	4.18E+05	557.30	1.54E+05	520	2.17E+06	4.57E-01	7.05E+04	1.620	2.08E+04	0.00E+00	9.14E+04
4	39	3.67	5.20E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.65	1.70E+05	520	2.50E+06	5.05E-01	8.59E+04	2.673	3.79E+04	0.00E+00	1.24E+05
4	40	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.59E+03	2.00E+05
4	41	3.78	5.22E+04	0.121	2.16E+04	0.00E+00	7.38E+04	559.00	1.66E+05	520	2.41E+06	4.92E-01	8.15E+04	5.076	7.01E+04	0.00E+00	1.52E+05
4	42	3.59	4.85E+04	0.191	3.42E+04	0.00E+00	8.26E+04	558.44	1.62E+05	520	2.33E+06	4.80E-01	7.78E+04	6.098	8.23E+04	0.00E+00	1.60E+05
4	43	4.09	5.39E+04	0.473	8.46E+04	0.00E+00	1.39E+05	557.89	1.58E+05	520	2.26E+06	4.69E-01	7.42E+04	5.905	7.79E+04	0.00E+00	1.52E+05
4	44	2.8	3.68E+04	0.125	2.24E+04	0.00E+00	5.91E+04	557.79	1.58E+05	520	2.24E+06	4.67E-01	7.36E+04	5.039	6.62E+04	0.00E+00	1.40E+05
4	45	2.59	3.32E+04	0.087	1.56E+04	0.00E+00	4.87E+04	557.21	1.54E+05	520	2.16E+06	4.55E-01	7.00E+04	4.036	5.17E+04	0.00E+00	1.22E+05
4	46	2.11	2.64E+04	0.016	2.86E+03	0.00E+00	2.93E+04	556.68	1.50E+05	520	2.09E+06	4.44E-01	6.68E+04	2.593	3.25E+04	0.00E+00	9.93E+04
4	47	3.01	3.69E+04	0.057	1.02E+04	0.00E+00	4.70E+04	556.18	1.47E+05	520	2.02E+06	4.34E-01	6.38E+04	1.558	1.91E+04	0.00E+00	8.29E+04
4	48	2.86	3.46E+04	0.187	3.34E+04	0.00E+00	6.81E+04	555.92	1.45E+05	520	1.98E+06	4.29E-01	6.23E+04	0.494	5.98E+03	0.00E+00	6.82E+04

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Table C-4
POND ROUTING UNDER NORMAL CONDITIONS
POND 4 (STORMWATER RETENTION POND) - FEMP

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (ft) = 3
Pond Bottom Elev. (ft) = 535
Drainage Area (ft^2) 2146500

Pond 4 Overflow El.= 560

Pond overflow at storage (ft^3): 2550000

POND 4

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft³)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft³)	Inflow from Pond 2 (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³)/day	Total Out flow O (ft³)
1	1	3.66	4.45E+04	1.242	2.22E+05	0.00E+00	2.67E+05	556.05	1.46E+05	520	2.00E+06	4.31E-01	6.30E+04	0.527	6.41E+03	0.00E+00	6.94E+04
1	2	2.98	3.86E+04	2.125	3.80E+05	0.00E+00	4.19E+05	557.47	1.55E+05	520	2.20E+06	4.60E-01	7.16E+04	1.620	2.10E+04	0.00E+00	9.26E+04
1	3	3.67	5.23E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.81	1.71E+05	520	2.52E+06	5.09E-01	8.70E+04	2.673	3.81E+04	0.00E+00	1.25E+05
1	4	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	2.32E+03	2.22E+05
1	5	3.78	5.19E+04	0.121	2.16E+04	0.00E+00	7.35E+04	558.85	1.65E+05	520	2.39E+06	4.89E-01	8.05E+04	5.076	6.96E+04	0.00E+00	1.50E+05
1	6	3.59	4.82E+04	0.191	3.42E+04	0.00E+00	8.23E+04	558.29	1.61E+05	520	2.31E+06	4.77E-01	7.69E+04	6.098	8.18E+04	0.00E+00	1.59E+05
1	7	4.09	5.36E+04	0.473	8.46E+04	0.00E+00	1.38E+05	557.75	1.57E+05	520	2.24E+06	4.66E-01	7.33E+04	5.905	7.74E+04	0.00E+00	1.51E+05
1	8	2.8	3.66E+04	0.125	2.24E+04	0.00E+00	5.89E+04	557.66	1.57E+05	520	2.22E+06	4.64E-01	7.28E+04	5.039	6.58E+04	0.00E+00	1.39E+05
1	9	2.59	3.30E+04	0.087	1.56E+04	0.00E+00	4.86E+04	557.08	1.53E+05	520	2.14E+06	4.53E-01	6.92E+04	4.036	5.14E+04	0.00E+00	1.21E+05
1	10	2.11	2.63E+04	0.016	2.86E+03	0.00E+00	2.91E+04	556.56	1.49E+05	520	2.07E+06	4.42E-01	6.61E+04	2.593	3.23E+04	0.00E+00	9.84E+04
1	11	3.01	3.67E+04	0.057	1.02E+04	0.00E+00	4.69E+04	556.07	1.46E+05	520	2.00E+06	4.32E-01	6.31E+04	1.558	1.90E+04	0.00E+00	8.21E+04
1	12	2.86	3.44E+04	0.187	3.34E+04	0.00E+00	6.79E+04	555.81	1.44E+05	520	1.97E+06	4.27E-01	6.16E+04	0.494	5.95E+03	0.00E+00	6.76E+04
2	13	3.66	4.41E+04	1.242	2.22E+05	0.00E+00	2.66E+05	555.82	1.44E+05	520	1.97E+06	4.27E-01	6.16E+04	0.527	6.34E+03	0.00E+00	6.80E+04
2	14	2.98	3.82E+04	2.125	3.80E+05	0.00E+00	4.18E+05	557.24	1.54E+05	520	2.17E+06	4.56E-01	7.02E+04	1.620	2.08E+04	0.00E+00	9.10E+04
2	15	3.67	5.19E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.60	1.70E+05	520	2.49E+06	5.04E-01	8.55E+04	2.673	3.78E+04	0.00E+00	1.23E+05
2	16	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.35E+03	1.93E+05
2	17	3.78	5.23E+04	0.121	2.16E+04	0.00E+00	7.40E+04	559.05	1.66E+05	520	2.42E+06	4.93E-01	8.19E+04	5.076	7.02E+04	0.00E+00	1.62E+05
2	18	3.59	4.86E+04	0.191	3.42E+04	0.00E+00	8.27E+04	558.49	1.62E+05	520	2.34E+06	4.81E-01	7.81E+04	6.098	8.25E+04	0.00E+00	1.61E+05
2	19	4.09	5.40E+04	0.473	8.46E+04	0.00E+00	1.39E+05	557.93	1.59E+05	520	2.26E+06	4.70E-01	7.45E+04	5.905	7.80E+04	0.00E+00	1.53E+05
2	20	2.8	3.68E+04	0.125	2.24E+04	0.00E+00	5.92E+04	557.83	1.58E+05	520	2.25E+06	4.68E-01	7.39E+04	5.039	6.63E+04	0.00E+00	1.40E+05
2	21	2.59	3.32E+04	0.087	1.56E+04	0.00E+00	4.88E+04	557.25	1.54E+05	520	2.17E+06	4.56E-01	7.02E+04	4.036	5.18E+04	0.00E+00	1.22E+05
2	22	2.11	2.65E+04	0.016	2.86E+03	0.00E+00	2.93E+04	556.72	1.51E+05	520	2.09E+06	4.45E-01	6.70E+04	2.593	3.25E+04	0.00E+00	9.95E+04
2	23	3.01	3.69E+04	0.057	1.02E+04	0.00E+00	4.71E+04	556.22	1.47E+05	520	2.02E+06	4.35E-01	6.40E+04	1.558	1.91E+04	0.00E+00	8.31E+04
2	24	2.86	3.47E+04	0.187	3.34E+04	0.00E+00	6.81E+04	555.96	1.45E+05	520	1.99E+06	4.30E-01	6.25E+04	0.494	5.99E+03	0.00E+00	6.85E+04
3	25	3.66	4.44E+04	1.242	2.22E+05	0.00E+00	2.67E+05	555.96	1.45E+05	520	1.99E+06	4.29E-01	6.25E+04	0.527	6.38E+03	0.00E+00	6.88E+04
3	26	2.98	3.85E+04	2.125	3.80E+05	0.00E+00	4.19E+05	557.38	1.55E+05	520	2.18E+06	4.59E-01	7.10E+04	1.620	2.09E+04	0.00E+00	9.19E+04
3	27	3.67	5.22E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.73	1.71E+05	520	2.51E+06	5.07E-01	8.64E+04	2.673	3.80E+04	0.00E+00	1.24E+05
3	28	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.94E+03	2.10E+05
3	29	3.78	5.20E+04	0.121	2.16E+04	0.00E+00	7.37E+04	558.93	1.65E+05	520	2.40E+06	4.90E-01	8.10E+04	5.076	6.99E+04	0.00E+00	1.51E+05

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POND 3

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3/Day	Total Out flow O (ft^3)
2	24	2.86	6.46E+04	0.187	7.06E+04	1.35E+05	576.23	2.71E+05	520	1.22E+06	2.30E-01	6.23E+04	0.494	1.12E+04	0.00E+00	7.35E+04
3	25	3.66	8.74E+04	1.242	4.69E+05	5.56E+05	576.38	2.87E+05	520	1.28E+06	2.33E-01	6.69E+04	0.527	1.26E+04	0.00E+00	7.95E+04
3	26	2.98	1.01E+05	2.125	8.02E+05	9.03E+05	577.57	4.09E+05	520	1.76E+06	2.58E-01	1.05E+05	1.620	5.52E+04	0.00E+00	1.60E+05
3	27	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.90E+04	7.92E+05
3	28	3.55	1.11E+05	0.053	2.00E+04	1.31E+05	577.26	3.77E+05	520	1.63E+06	2.51E-01	9.47E+04	4.437	1.39E+05	0.00E+00	2.34E+05
3	29	3.78	1.10E+05	0.121	4.57E+04	1.56E+05	577.01	3.51E+05	520	1.53E+06	2.46E-01	8.63E+04	5.076	1.48E+05	0.00E+00	2.35E+05
3	30	3.59	9.89E+04	0.191	7.21E+04	1.71E+05	576.81	3.31E+05	520	1.45E+06	2.42E-01	8.00E+04	6.098	1.68E+05	0.00E+00	2.48E+05
3	31	4.09	1.06E+05	0.473	1.78E+05	2.84E+05	576.62	3.11E+05	520	1.38E+06	2.38E-01	7.40E+04	5.905	1.53E+05	0.00E+00	2.27E+05
3	32	2.8	7.60E+04	0.125	4.72E+04	1.23E+05	576.76	3.26E+05	520	1.43E+06	2.41E-01	7.85E+04	5.039	1.37E+05	0.00E+00	2.15E+05
3	33	2.59	6.52E+04	0.087	3.28E+04	9.80E+04	576.53	3.02E+05	520	1.34E+06	2.36E-01	7.14E+04	4.036	1.02E+05	0.00E+00	1.73E+05
3	34	2.11	4.97E+04	0.016	6.04E+03	5.58E+04	576.35	2.83E+05	520	1.27E+06	2.33E-01	6.58E+04	2.593	6.11E+04	0.00E+00	1.27E+05
3	35	3.01	6.64E+04	0.057	2.15E+04	8.79E+04	576.17	2.65E+05	520	1.20E+06	2.29E-01	6.06E+04	1.558	3.43E+04	0.00E+00	9.49E+04
3	36	2.86	6.26E+04	0.187	7.06E+04	1.33E+05	576.15	2.63E+05	520	1.19E+06	2.29E-01	6.01E+04	0.494	1.08E+04	0.00E+00	7.09E+04
4	37	3.66	8.50E+04	1.242	4.69E+05	5.54E+05	576.31	2.79E+05	520	1.25E+06	2.32E-01	6.46E+04	0.527	1.22E+04	0.00E+00	7.68E+04
4	38	2.98	9.95E+04	2.125	8.02E+05	9.01E+05	577.49	4.01E+05	520	1.73E+06	2.56E-01	1.03E+05	1.620	5.41E+04	0.00E+00	1.57E+05
4	39	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.80E+04	7.63E+05
4	40	3.55	1.14E+05	0.053	2.00E+04	1.34E+05	577.33	3.84E+05	520	1.66E+06	2.53E-01	9.71E+04	4.437	1.42E+05	0.00E+00	2.39E+05
4	41	3.78	1.13E+05	0.121	4.57E+04	1.58E+05	577.07	3.57E+05	520	1.56E+06	2.47E-01	8.84E+04	5.076	1.51E+05	0.00E+00	2.39E+05
4	42	3.59	1.01E+05	0.191	7.21E+04	1.73E+05	576.87	3.36E+05	520	1.48E+06	2.43E-01	8.18E+04	6.098	1.71E+05	0.00E+00	2.53E+05
4	43	4.09	1.08E+05	0.473	1.78E+05	2.86E+05	576.67	3.16E+05	520	1.40E+06	2.39E-01	7.56E+04	5.905	1.55E+05	0.00E+00	2.31E+05
4	44	2.8	7.70E+04	0.125	4.72E+04	1.24E+05	576.81	3.30E+05	520	1.45E+06	2.42E-01	7.99E+04	5.039	1.39E+05	0.00E+00	2.18E+05
4	45	2.59	6.60E+04	0.087	3.28E+04	9.89E+04	576.57	3.06E+05	520	1.36E+06	2.37E-01	7.25E+04	4.036	1.03E+05	0.00E+00	1.75E+05
4	46	2.11	5.03E+04	0.016	6.04E+03	5.64E+04	576.38	2.86E+05	520	1.28E+06	2.33E-01	6.68E+04	2.593	6.19E+04	0.00E+00	1.29E+05
4	47	3.01	6.72E+04	0.057	2.15E+04	8.87E+04	576.20	2.68E+05	520	1.21E+06	2.30E-01	6.15E+04	1.558	3.48E+04	0.00E+00	9.62E+04
4	48	2.86	6.34E+04	0.187	7.06E+04	1.34E+05	576.18	2.66E+05	520	1.20E+06	2.29E-01	6.09E+04	0.494	1.10E+04	0.00E+00	7.19E+04

Table C-3
POND ROUTING UNDER NORMAL CONDITIONS
POND 3 (SOUTHEAST OF FEMP, BORROWED AREA)

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of
Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (ft 3
Pond Bottom Elev. (ft) = 565
Drainage Area (ft^2) 4528350

Pond 3 Overflow El.= 578

Pond overflow at storage (ft^3): 1931500

POND 3

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft³)	Runoff Depth (inch)	Runoff Vol. into Pond (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³)/Day	Total Out flow O (ft³)
1	1	3.66	1.04E+05	1.242	4.69E+05	5.73E+05	576.93	3.42E+05	520	1.50E+06	2.44E-01	8.37E+04	0.527	1.50E+04	0.00E+00	9.87E+04
1	2	2.98	1.12E+05	2.125	8.02E+05	9.14E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	1.620	6.11E+04	1.43E+03	2.25E+05
1	3	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	2.30E+04	9.11E+05
1	4	3.55	1.02E+05	0.053	2.00E+04	1.22E+05	576.96	3.46E+05	520	1.52E+06	2.45E-01	8.49E+04	4.437	1.28E+05	0.00E+00	2.13E+05
1	5	3.78	1.02E+05	0.121	4.57E+04	1.47E+05	576.74	3.23E+05	520	1.42E+06	2.41E-01	7.77E+04	5.076	1.37E+05	0.00E+00	2.14E+05
1	6	3.59	9.15E+04	0.191	7.21E+04	1.64E+05	576.57	3.06E+05	520	1.36E+06	2.37E-01	7.26E+04	6.098	1.55E+05	0.00E+00	2.28E+05
1	7	4.09	9.87E+04	0.473	1.78E+05	2.77E+05	576.41	2.90E+05	520	1.29E+06	2.34E-01	6.77E+04	5.905	1.42E+05	0.00E+00	2.10E+05
1	8	2.8	7.16E+04	0.125	4.72E+04	1.19E+05	576.58	3.07E+05	520	1.36E+06	2.37E-01	7.28E+04	5.039	1.29E+05	0.00E+00	2.02E+05
1	9	2.59	6.16E+04	0.087	3.28E+04	9.44E+04	576.37	2.85E+05	520	1.28E+06	2.33E-01	6.65E+04	4.036	9.60E+04	0.00E+00	1.63E+05
1	10	2.11	4.71E+04	0.016	6.04E+03	5.32E+04	576.20	2.68E+05	520	1.21E+06	2.30E-01	6.15E+04	2.593	5.79E+04	0.00E+00	1.19E+05
1	11	3.01	6.30E+04	0.057	2.15E+04	8.45E+04	576.04	2.51E+05	520	1.14E+06	2.26E-01	5.68E+04	1.558	3.26E+04	0.00E+00	8.94E+04
1	12	2.86	5.95E+04	0.187	7.06E+04	1.30E+05	576.02	2.50E+05	520	1.14E+06	2.26E-01	5.64E+04	0.494	1.03E+04	0.00E+00	6.67E+04
2	13	3.66	8.11E+04	1.242	4.69E+05	5.50E+05	576.18	2.66E+05	520	1.20E+06	2.29E-01	6.10E+04	0.527	1.17E+04	0.00E+00	7.26E+04
2	14	2.98	9.64E+04	2.125	8.02E+05	8.98E+05	577.37	3.88E+05	520	1.68E+06	2.54E-01	9.84E+04	1.620	5.24E+04	0.00E+00	1.51E+05
2	15	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.65E+04	7.16E+05
2	16	3.55	1.17E+05	0.053	2.00E+04	1.37E+05	577.45	3.96E+05	520	1.71E+06	2.55E-01	1.01E+05	4.437	1.46E+05	0.00E+00	2.48E+05
2	17	3.78	1.16E+05	0.121	4.57E+04	1.62E+05	577.17	3.68E+05	520	1.60E+06	2.50E-01	9.18E+04	5.076	1.56E+05	0.00E+00	2.47E+05
2	18	3.59	1.03E+05	0.191	7.21E+04	1.76E+05	576.96	3.46E+05	520	1.51E+06	2.45E-01	8.48E+04	6.098	1.76E+05	0.00E+00	2.61E+05
2	19	4.09	1.10E+05	0.473	1.78E+05	2.89E+05	576.75	3.24E+05	520	1.43E+06	2.41E-01	7.81E+04	5.905	1.60E+05	0.00E+00	2.38E+05
2	20	2.8	7.87E+04	0.125	4.72E+04	1.26E+05	576.88	3.37E+05	520	1.48E+06	2.43E-01	8.21E+04	5.039	1.42E+05	0.00E+00	2.24E+05
2	21	2.59	6.74E+04	0.087	3.28E+04	1.00E+05	576.63	3.12E+05	520	1.38E+06	2.38E-01	7.45E+04	4.036	1.05E+05	0.00E+00	1.79E+05
2	22	2.11	5.13E+04	0.016	6.04E+03	5.74E+04	576.44	2.92E+05	520	1.30E+06	2.34E-01	6.84E+04	2.593	6.31E+04	0.00E+00	1.32E+05
2	23	3.01	6.85E+04	0.057	2.15E+04	9.00E+04	576.25	2.73E+05	520	1.23E+06	2.31E-01	6.29E+04	1.558	3.54E+04	0.00E+00	9.84E+04

POND 2

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft^3)	Runoff Depth (inch)	Runoff Into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3/day	Total Out flow O (ft^3)
2	24	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.15	5.42E+05	520	4.72E+06	2.90E-01	1.57E+05	0.494	2.23E+04	0.00E+00	1.79E+05
3	25	3.66	1.66E+05	1.242	4.92E+05	6.58E+05	564.19	5.43E+05	520	4.74E+06	2.91E-01	1.58E+05	0.527	2.38E+04	0.00E+00	1.82E+05
3	26	2.98	1.39E+05	2.125	8.42E+05	9.81E+05	565.11	5.61E+05	520	5.22E+06	3.10E-01	1.74E+05	1.620	7.58E+04	0.00E+00	2.50E+05
3	27	3.67	1.79E+05	0.945	3.74E+05	5.53E+05	566.32	5.84E+05	520	5.95E+06	3.34E-01	1.95E+05	2.673	1.30E+05	0.00E+00	3.25E+05
3	28	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.69	5.91E+05	520	6.18E+06	3.42E-01	2.02E+05	4.437	2.19E+05	0.00E+00	4.21E+05
3	29	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.32	5.84E+05	520	5.95E+06	3.34E-01	1.95E+05	5.076	2.47E+05	0.00E+00	4.43E+05
3	30	3.59	1.73E+05	0.191	7.57E+04	2.49E+05	565.97	5.78E+05	520	5.74E+06	3.27E-01	1.89E+05	6.098	2.94E+05	0.00E+00	4.83E+05
3	31	4.09	1.94E+05	0.473	1.87E+05	3.82E+05	565.59	5.70E+05	520	5.51E+06	3.19E-01	1.82E+05	5.905	2.81E+05	0.00E+00	4.63E+05
3	32	2.8	1.33E+05	0.125	4.95E+04	1.82E+05	565.45	5.68E+05	520	5.43E+06	3.17E-01	1.80E+05	5.039	2.38E+05	0.00E+00	4.18E+05
3	33	2.59	1.21E+05	0.087	3.45E+04	1.55E+05	565.06	5.61E+05	520	5.19E+06	3.09E-01	1.73E+05	4.036	1.89E+05	0.00E+00	3.62E+05
3	34	2.11	9.72E+04	0.016	6.34E+03	1.04E+05	564.67	5.53E+05	520	4.98E+06	3.01E-01	1.66E+05	2.593	1.19E+05	0.00E+00	2.86E+05
3	35	3.01	1.37E+05	0.057	2.26E+04	1.59E+05	564.31	5.45E+05	520	4.80E+06	2.93E-01	1.60E+05	1.558	7.08E+04	0.00E+00	2.31E+05
3	36	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.17	5.42E+05	520	4.73E+06	2.90E-01	1.58E+05	0.494	2.23E+04	0.00E+00	1.80E+05
4	37	3.66	1.66E+05	1.242	4.92E+05	6.58E+05	564.22	5.43E+05	520	4.75E+06	2.91E-01	1.58E+05	0.527	2.38E+04	0.00E+00	1.82E+05
4	38	2.98	1.40E+05	2.125	8.42E+05	9.81E+05	565.13	5.62E+05	520	5.23E+06	3.10E-01	1.74E+05	1.620	7.58E+04	0.00E+00	2.50E+05
4	39	3.67	1.79E+05	0.945	3.74E+05	5.53E+05	566.33	5.85E+05	520	5.96E+06	3.35E-01	1.96E+05	2.673	1.30E+05	0.00E+00	3.26E+05
4	40	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.71	5.92E+05	520	6.19E+06	3.42E-01	2.03E+05	4.437	2.19E+05	0.00E+00	4.21E+05
4	41	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.34	5.85E+05	520	5.96E+06	3.35E-01	1.96E+05	5.076	2.47E+05	0.00E+00	4.43E+05
4	42	3.59	1.73E+05	0.191	7.57E+04	2.49E+05	565.99	5.78E+05	520	5.75E+06	3.28E-01	1.89E+05	6.098	2.94E+05	0.00E+00	4.83E+05
4	43	4.09	1.95E+05	0.473	1.87E+05	3.82E+05	565.60	5.71E+05	520	5.52E+06	3.20E-01	1.83E+05	5.905	2.81E+05	0.00E+00	4.63E+05
4	44	2.8	1.33E+05	0.125	4.95E+04	1.82E+05	565.47	5.68E+05	520	5.44E+06	3.17E-01	1.80E+05	5.039	2.39E+05	0.00E+00	4.19E+05
4	45	2.59	1.21E+05	0.087	3.45E+04	1.56E+05	565.08	5.61E+05	520	5.20E+06	3.09E-01	1.73E+05	4.036	1.89E+05	0.00E+00	3.62E+05
4	46	2.11	9.72E+04	0.016	6.34E+03	1.04E+05	564.69	5.53E+05	520	4.99E+06	3.01E-01	1.66E+05	2.593	1.20E+05	0.00E+00	2.86E+05
4	47	3.01	1.37E+05	0.057	2.26E+04	1.59E+05	564.33	5.46E+05	520	4.81E+06	2.94E-01	1.60E+05	1.558	7.08E+04	0.00E+00	2.31E+05
4	48	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.19	5.43E+05	520	4.74E+06	2.91E-01	1.58E+05	0.494	2.24E+04	0.00E+00	1.80E+05

352
393

296

Table C-2
POND ROUTING
POND 2 (SOUTH OF PADR) - FEMP

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of Pond Liner (cm/sec) = 7 23E-07
Thickness of Pond Liner (ft 3
Pond Bottom Elev. (ft) = 550
Drainage Area (ft^2) 4753800

Pond 2 Overflow El.= 573

Pond overflow at storage (ft^3). 10669000

POND 2

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft³)	Runoff Depth (inch)	Runoff Into Pond (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³)/day	Total Out flow O (ft³)
1	1	3.66	1.65E+05	1.242	4.92E+05	6.57E+05	564.11	5.41E+05	520	4.70E+06	2.89E-01	1.56E+05	0.527	2.37E+04	0.00E+00	1.80E+05
1	2	2.98	1.39E+05	2.125	8.42E+05	9.81E+05	565.04	5.60E+05	520	5.18E+06	3.08E-01	1.73E+05	1.620	7.56E+04	0.00E+00	2.48E+05
1	3	3.67	1.78E+05	0.945	3.74E+05	5.53E+05	566.25	5.83E+05	520	5.91E+06	3.33E-01	1.94E+05	2.673	1.30E+05	0.00E+00	3.24E+05
1	4	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.63	5.90E+05	520	6.14E+06	3.41E-01	2.01E+05	4.437	2.18E+05	0.00E+00	4.19E+05
1	5	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.26	5.83E+05	520	5.91E+06	3.33E-01	1.94E+05	5.076	2.47E+05	0.00E+00	4.41E+05
1	6	3.59	1.73E+05	0.191	7.57E+04	2.48E+05	565.91	5.77E+05	520	5.71E+06	3.26E-01	1.88E+05	6.098	2.93E+05	0.00E+00	4.81E+05
1	7	4.09	1.94E+05	0.473	1.87E+05	3.81E+05	565.53	5.69E+05	520	5.47E+06	3.18E-01	1.81E+05	5.905	2.80E+05	0.00E+00	4.61E+05
1	8	2.8	1.32E+05	0.125	4.95E+04	1.82E+05	565.40	5.67E+05	520	5.39E+06	3.16E-01	1.79E+05	5.039	2.38E+05	0.00E+00	4.17E+05
1	9	2.59	1.21E+05	0.087	3.45E+04	1.55E+05	565.01	5.60E+05	520	5.16E+06	3.08E-01	1.72E+05	4.036	1.88E+05	0.00E+00	3.60E+05
1	10	2.11	9.69E+04	0.016	6.34E+03	1.03E+05	564.61	5.51E+05	520	4.95E+06	2.99E-01	1.65E+05	2.593	1.19E+05	0.00E+00	2.84E+05
1	11	3.01	1.36E+05	0.057	2.26E+04	1.59E+05	564.25	5.44E+05	520	4.77E+06	2.92E-01	1.59E+05	1.558	7.06E+04	0.00E+00	2.29E+05
1	12	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.11	5.41E+05	520	4.70E+06	2.89E-01	1.57E+05	0.494	2.23E+04	0.00E+00	1.79E+05
2	13	3.66	1.65E+05	1.242	4.92E+05	6.57E+05	564.16	5.42E+05	520	4.72E+06	2.90E-01	1.57E+05	0.527	2.38E+04	0.00E+00	1.81E+05
2	14	2.98	1.39E+05	2.125	8.42E+05	9.81E+05	565.08	5.61E+05	520	5.20E+06	3.09E-01	1.73E+05	1.620	7.57E+04	0.00E+00	2.49E+05
2	15	3.67	1.79E+05	0.945	3.74E+05	5.53E+05	566.29	5.84E+05	520	5.93E+06	3.34E-01	1.95E+05	2.673	1.30E+05	0.00E+00	3.25E+05
2	16	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.66	5.91E+05	520	6.16E+06	3.42E-01	2.02E+05	4.437	2.18E+05	0.00E+00	4.20E+05
2	17	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.29	5.84E+05	520	5.94E+06	3.34E-01	1.95E+05	5.076	2.47E+05	0.00E+00	4.42E+05
2	18	3.59	1.73E+05	0.191	7.57E+04	2.48E+05	565.95	5.77E+05	520	5.73E+06	3.27E-01	1.89E+05	6.098	2.93E+05	0.00E+00	4.82E+05
2	19	4.09	1.94E+05	0.473	1.87E+05	3.82E+05	565.56	5.70E+05	520	5.49E+06	3.19E-01	1.82E+05	5.905	2.80E+05	0.00E+00	4.62E+05
2	20	2.8	1.32E+05	0.125	4.95E+04	1.82E+05	565.43	5.68E+05	520	5.41E+06	3.16E-01	1.79E+05	5.039	2.38E+05	0.00E+00	4.18E+05
2	21	2.59	1.21E+05	0.087	3.45E+04	1.55E+05	565.04	5.60E+05	520	5.18E+06	3.08E-01	1.73E+05	4.036	1.88E+05	0.00E+00	3.61E+05
2	22	2.11	9.71E+04	0.016	6.34E+03	1.03E+05	564.64	5.52E+05	520	4.97E+06	3.00E-01	1.66E+05	2.593	1.19E+05	0.00E+00	2.85E+05
2	23	3.01	1.37E+05	0.057	2.26E+04	1.59E+05	564.29	5.45E+05	520	4.79E+06	2.93E-01	1.59E+05	1.558	7.07E+04	0.00E+00	2.30E+05

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POND 1

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft ^{3})	Runoff Depth (inch)	Runoff Vol. into Pond (ft ^{3})	Total Inflow I (ft ^{3})	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft ^{3})	Infiltration Rate (ft)	Total Infiltration (ft ^{3})	Monthly Evapo. (inch)	Total Evapo. (ft ^{3})	Pond Overflow (ft ^{3})/day	Total Out flow O (ft ^{3})
3	27	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.77E+03	3.73E+05
3	28	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.65E+03	6.29E+05
3	29	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.15	5.08E+05	520	4.00E+06	3.51E-01	1.78E+05	5.076	2.15E+05	0.00E+00	3.93E+05
3	30	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.81	4.95E+05	520	3.82E+06	3.44E-01	1.70E+05	6.098	2.51E+05	0.00E+00	4.22E+05
3	31	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.45	4.81E+05	520	3.64E+06	3.37E-01	1.62E+05	5.905	2.37E+05	0.00E+00	3.99E+05
3	32	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.42	4.80E+05	520	3.62E+06	3.37E-01	1.62E+05	5.039	2.02E+05	0.00E+00	3.63E+05
3	33	2.59	1.01E+05	0.087	4.02E+04	1.41E+05	571.05	4.66E+05	520	3.43E+06	3.29E-01	1.53E+05	4.036	1.57E+05	0.00E+00	3.10E+05
3	34	2.11	7.97E+04	0.016	7.40E+03	8.71E+04	570.73	4.53E+05	520	3.26E+06	3.22E-01	1.46E+05	2.593	9.80E+04	0.00E+00	2.44E+05
3	35	3.01	1.11E+05	0.057	2.64E+04	1.37E+05	570.42	4.42E+05	520	3.10E+06	3.16E-01	1.40E+05	1.558	5.73E+04	0.00E+00	1.97E+05
3	36	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.31	4.37E+05	520	3.04E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
4	37	3.66	1.34E+05	1.242	5.74E+05	7.09E+05	570.38	4.40E+05	520	3.08E+06	3.15E-01	1.39E+05	0.527	1.93E+04	0.00E+00	1.58E+05
4	38	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.43	4.81E+05	520	3.63E+06	3.37E-01	1.62E+05	1.620	6.49E+04	0.00E+00	2.27E+05
4	39	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.96E+03	3.79E+05
4	40	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.46E+03	6.23E+05
4	41	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.16	5.08E+05	520	4.01E+06	3.52E-01	1.79E+05	5.076	2.15E+05	0.00E+00	3.94E+05
4	42	3.59	1.48E+05	0.191	8.83E+04	2.37E+05	571.82	4.95E+05	520	3.83E+06	3.45E-01	1.71E+05	6.098	2.52E+05	0.00E+00	4.22E+05
4	43	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.46	4.82E+05	520	3.64E+06	3.37E-01	1.62E+05	5.905	2.37E+05	0.00E+00	3.99E+05
4	44	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.43	4.80E+05	520	3.63E+06	3.37E-01	1.62E+05	5.039	2.02E+05	0.00E+00	3.63E+05
4	45	2.59	1.01E+05	0.087	4.02E+04	1.41E+05	571.06	4.66E+05	520	3.43E+06	3.29E-01	1.53E+05	4.036	1.57E+05	0.00E+00	3.10E+05
4	46	2.11	7.98E+04	0.016	7.40E+03	8.72E+04	570.73	4.54E+05	520	3.26E+06	3.22E-01	1.46E+05	2.593	9.80E+04	0.00E+00	2.44E+05
4	47	3.01	1.11E+05	0.057	2.64E+04	1.37E+05	570.43	4.42E+05	520	3.11E+06	3.16E-01	1.40E+05	1.558	5.74E+04	0.00E+00	1.97E+05
4	48	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.32	4.38E+05	520	3.05E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05

BROWN & ROOT ENVIRONMENTAL

Table C-1
POND ROUTING UNDER NORMAL CONDITIONS
POND 1 (NORTHEAST OF FEMP)

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (f 3
Pond Bottom Elev. (ft) = 555
Drainage Area (ft^2) 5,550,300

Pond 1 Overflow El.= 573

Pond overflow at storage (ft^3): 4445400

POND 1

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3/day	Total Out flow O (ft^3)
1	1	3.66	1.46E+05	1.242	5.74E+05	7.20E+05	571.38	4.78E+05	520	3.60E+06	3.36E-01	1.61E+05	0.527	2.10E+04	0.00E+00	1.82E+05
1	2	2.98	1.29E+05	2.125	9.83E+05	1.11E+06	572.41	5.18E+05	520	4.14E+06	3.57E-01	1.85E+05	1.620	6.99E+04	0.00E+00	2.55E+05
1	3	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.83E+04	8.70E+05
1	4	3.55	1.54E+05	0.053	2.45E+04	1.79E+05	572.49	5.21E+05	520	4.18E+06	3.58E-01	1.87E+05	4.437	1.93E+05	0.00E+00	3.79E+05
1	5	3.78	1.59E+05	0.121	5.60E+04	2.15E+05	572.10	5.06E+05	520	3.98E+06	3.51E-01	1.77E+05	5.076	2.14E+05	0.00E+00	3.91E+05
1	6	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.76	4.93E+05	520	3.80E+06	3.44E-01	1.69E+05	6.098	2.51E+05	0.00E+00	4.20E+05
1	7	4.09	1.63E+05	0.473	2.19E+05	3.82E+05	571.41	4.80E+05	520	3.62E+06	3.36E-01	1.61E+05	5.905	2.36E+05	0.00E+00	3.97E+05
1	8	2.8	1.12E+05	0.125	5.78E+04	1.69E+05	571.38	4.79E+05	520	3.60E+06	3.36E-01	1.61E+05	5.039	2.01E+05	0.00E+00	3.62E+05
1	9	2.59	1.00E+05	0.087	4.02E+04	1.40E+05	571.01	4.64E+05	520	3.41E+06	3.28E-01	1.52E+05	4.036	1.56E+05	0.00E+00	3.09E+05
1	10	2.11	7.95E+04	0.016	7.40E+03	8.69E+04	570.69	4.52E+05	520	3.24E+06	3.22E-01	1.45E+05	2.593	9.77E+04	0.00E+00	2.43E+05
1	11	3.01	1.10E+05	0.057	2.64E+04	1.37E+05	570.39	4.41E+05	520	3.09E+06	3.15E-01	1.39E+05	1.558	5.72E+04	0.00E+00	1.96E+05
1	12	2.86	1.04E+05	0.187	8.65E+04	1.90E+05	570.28	4.36E+05	520	3.03E+06	3.13E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
2	13	3.66	1.34E+05	1.242	5.74E+05	7.08E+05	570.35	4.39E+05	520	3.06E+06	3.15E-01	1.38E+05	0.527	1.93E+04	0.00E+00	1.57E+05
2	14	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.40	4.78E+05	520	3.61E+06	3.36E-01	1.61E+05	1.620	6.47E+04	0.00E+00	2.26E+05
2	15	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.46E+03	3.64E+05
2	16	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.96E+03	6.38E+05
2	17	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.13	5.07E+05	520	3.99E+06	3.51E-01	1.78E+05	5.076	2.15E+05	0.00E+00	3.93E+05
2	18	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.79	4.94E+05	520	3.81E+06	3.44E-01	1.70E+05	6.098	2.51E+05	0.00E+00	4.21E+05
2	19	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.44	4.81E+05	520	3.63E+06	3.37E-01	1.62E+05	5.905	2.36E+05	0.00E+00	3.98E+05
2	20	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.41	4.79E+05	520	3.61E+06	3.36E-01	1.61E+05	5.039	2.01E+05	0.00E+00	3.62E+05
2	21	2.59	1.00E+05	0.087	4.02E+04	1.41E+05	571.04	4.65E+05	520	3.42E+06	3.29E-01	1.53E+05	4.036	1.56E+05	0.00E+00	3 09E+05
2	22	2.11	7.96E+04	0.016	7.40E+03	8.70E+04	570.71	4.53E+05	520	3.25E+06	3.22E-01	1.46E+05	2.593	9.79E+04	0.00E+00	2.44E+05
2	23	3.01	1.11E+05	0.057	2.64E+04	1.37E+05	570.41	4.41E+05	520	3.10E+06	3.16E-01	1.39E+05	1.558	5.73E+04	0.00E+00	1.97E+05
2	24	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.30	4.37E+05	520	3.04E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
3	25	3.66	1.34E+05	1.242	5.74E+05	7.09E+05	570.37	4.40E+05	520	3.07E+06	3.15E-01	1.38E+05	0.527	1.93E+04	0.00E+00	1.58E+05
3	26	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.42	4.80E+05	520	3.62E+06	3.37E-01	1.62E+05	1.620	6.48E+04	0.00E+00	2.26E+05